Effects of Hydropower Operations on Spawning Habitat, Rearing Habitat, and Stranding/Entrapment Mortality of Fall Chinook Salmon in the Hanford Reach of the Columbia River

U.S. Fish and Wildlife Service

Cooperators:

U.S. Geological Survey

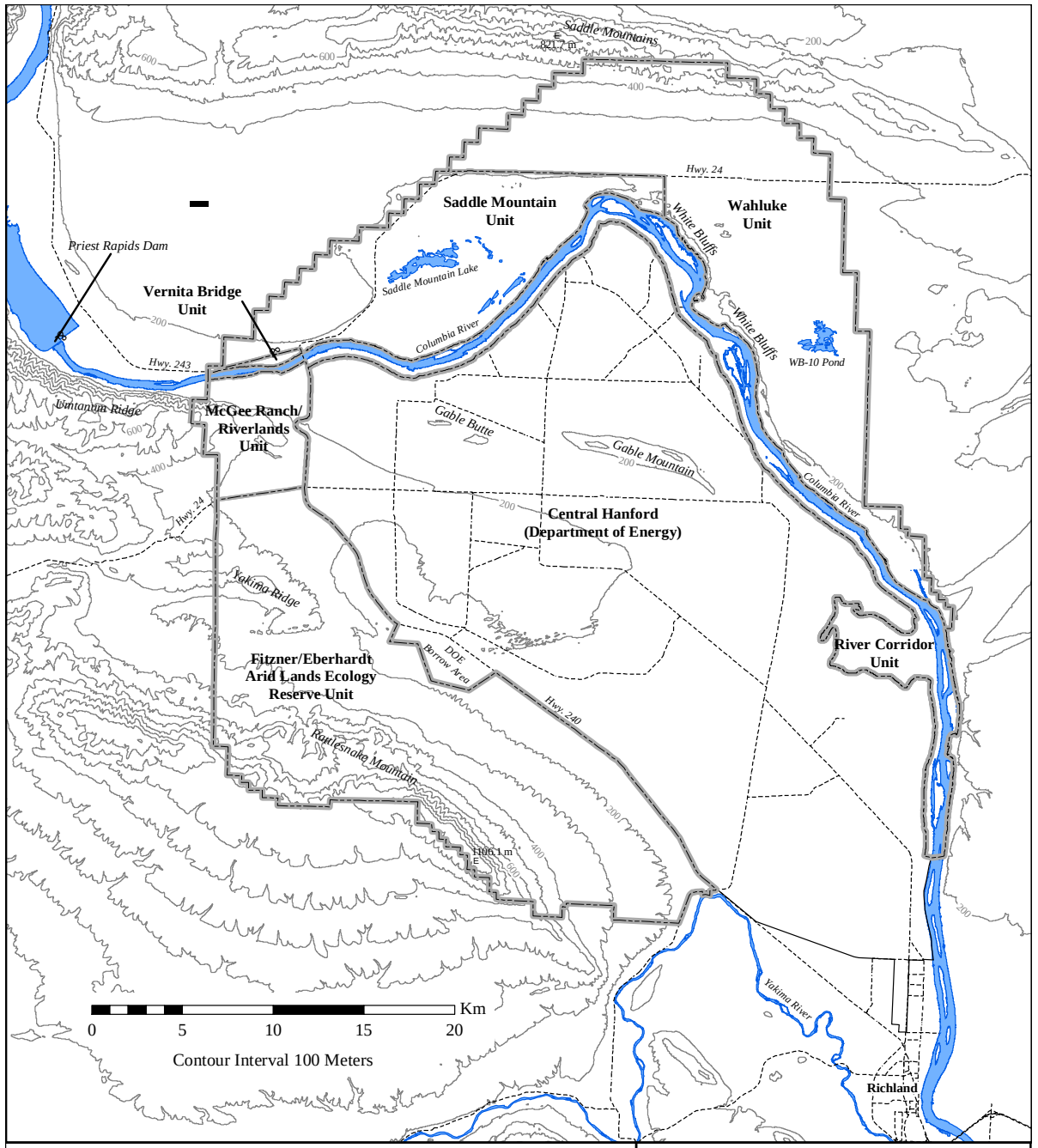
Columbia River Inter-Tribal Fish Commission

Washington Department of Fish and Wildlife

Alaska Department of Fish and Game

Presentation Outline

- Population Information
- Management Background
- Study Goals and Objectives
- Entrapment
- Spawning and Rearing Habitat
- Conclusions


Saddle Mountains
821 m
Hwy. 24
Saddle Mountain Unit
Wahluke Unit
White Bluffs
Priest Rapids Dam
Vernita Bridge Unit
Saddle Mountain Lake
Columbia River
White Bluffs
WB-10 Pond
Hwy. 243
Umtanum Ridge
McGee Ranch/ Riverlands Unit
Gable Butte
Gable Mountain
Columbia River
Hwy. 24
Central Hanford (Department of Energy)
Yakima Ridge
River Corridor Unit
Fitzner/Eberhardt Arid Lands Ecology Reserve Unit
DOE Borrow Area
Hwy. 240
Rattlesnake Mountain
1106.1 m
Km
0 5 10 15 20
Contour Interval 100 Meters
Yakima River
Richland
Legend
Hanford Reach National Monument Boundary
Management Unit Boundaries
Central Hanford Boundary
Roads
Open Water
Seattle
Spokane
Portland

FWS Responsibilities

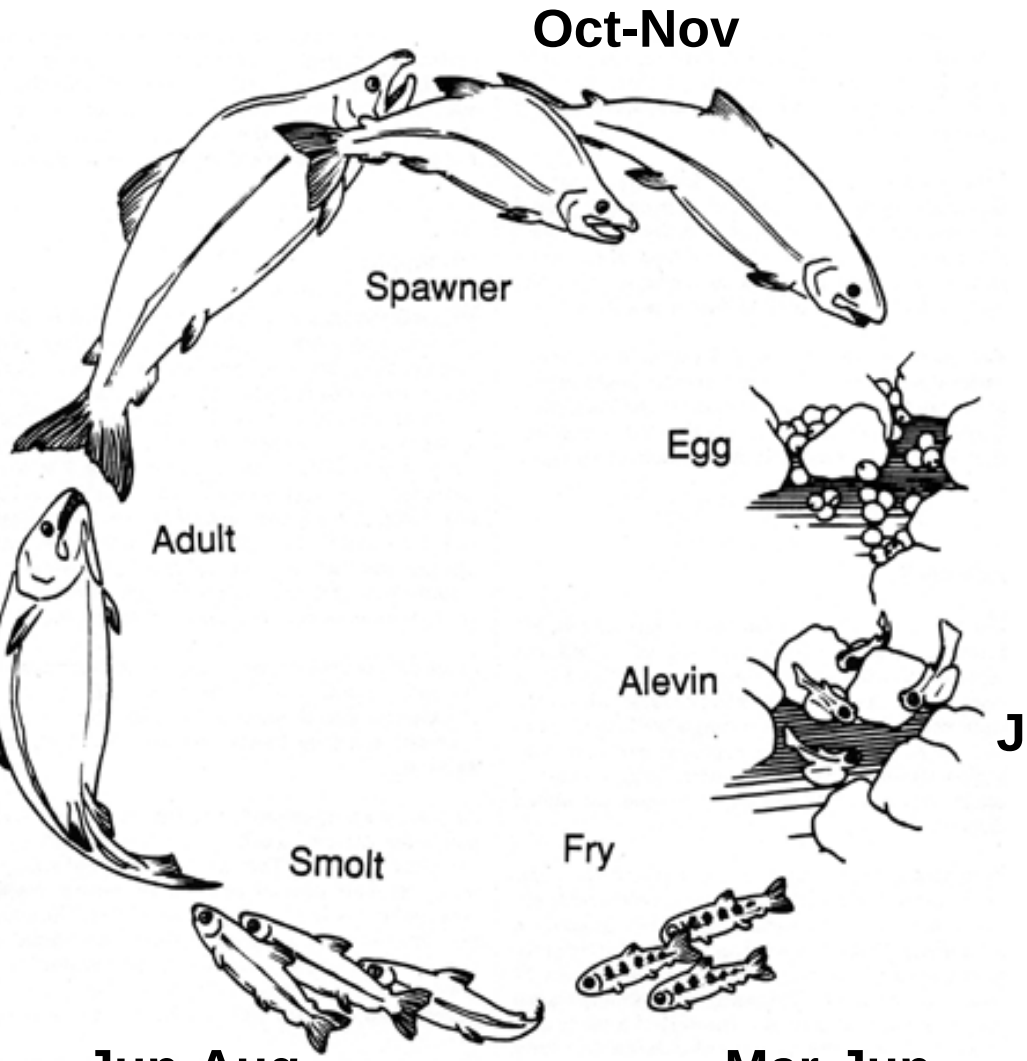
- Assist in management of tribal treaty and public trust aquatic resources

- Develop tools for identifying Terms and Conditions for FERC Hydro licenses

Hanford Reach Fish Resources

- Chinook, coho, and sockeye salmon, steelhead trout, and Pacific lamprey migrate through or spawn
- Produces one of the world's largest runs of Chinook salmon
- White sturgeon spawn in the Reach from early June through mid July
- Mountain whitefish are common in the Reach
- Other native resident species

Upper Columbia River Bright Fall Chinook Life-Cycle



History of Hanford Reach Fall Chinook Management

- A far-north migrating stock caught in SE Alaska and British Columbia ocean fisheries and Columbia River fisheries
- Reach population levels observed in the early 1980s were a driving force for reducing ocean exploitation rates for Chinook salmon coastwide.
- PSC instituted Coastwide Chinook harvest conservation program in mid 1980s
- During this period, in-river harvest restrictions were being implemented through US vs Oregon.
- Further harvest reductions in the mid 1990s when Snake River fall Chinook were listed under ESA.
- Increases in escapements may also be due to improvements in fish passage.

Water Management Issues
Juvenile Chinook Rearing

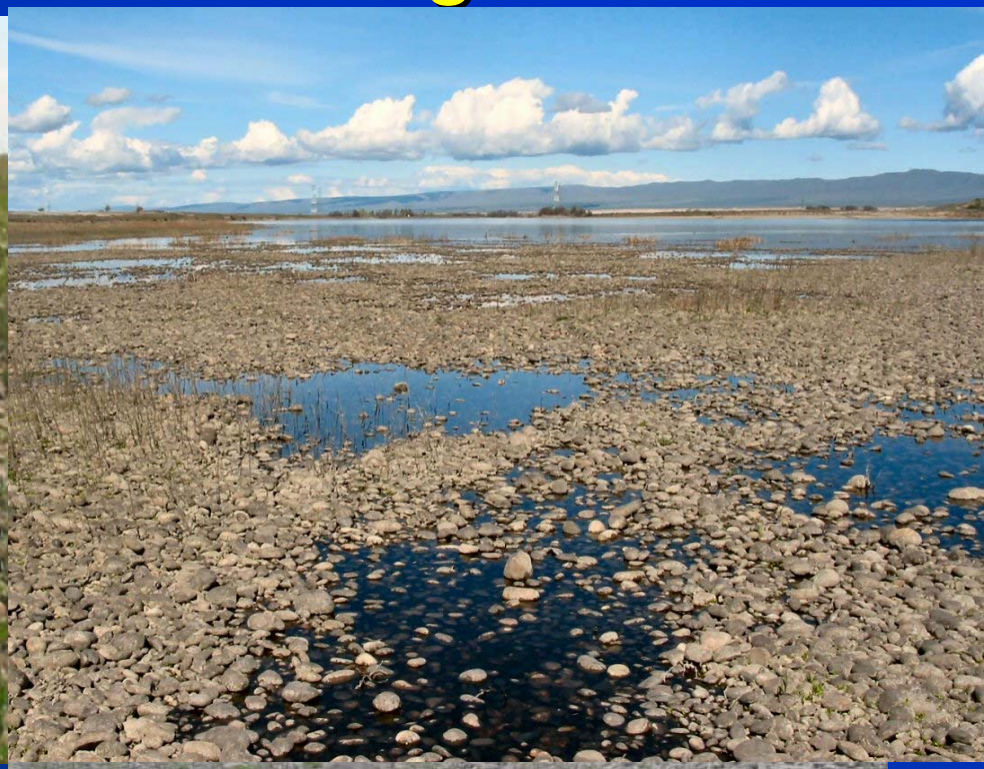
- Flow fluctuations from hydropower operations
- Photos taken 3 hours apart

Water Management Issues
Juvenile Chinook Rearing

- **Entrapment of juveniles rearing in nearshore areas**

Water Management Issues
Juvenile Chinook Rearing

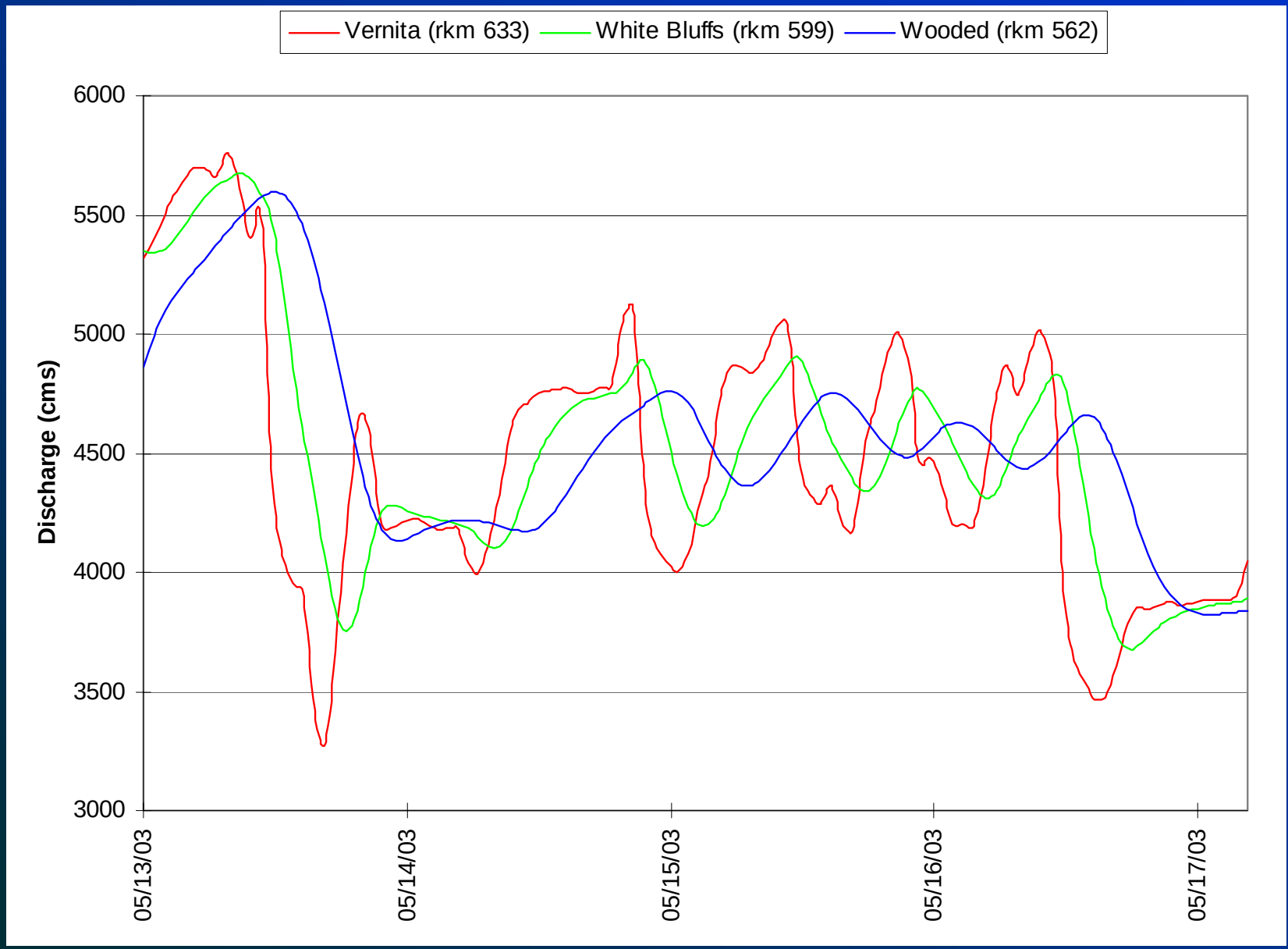
- **Stranding of juveniles rearing in nearshore areas**



Water Management Issues

Juvenile Chinook Rearing

- **Effects vary throughout the Reach due to variable channel morphology and variable amplitude and duration of flows**

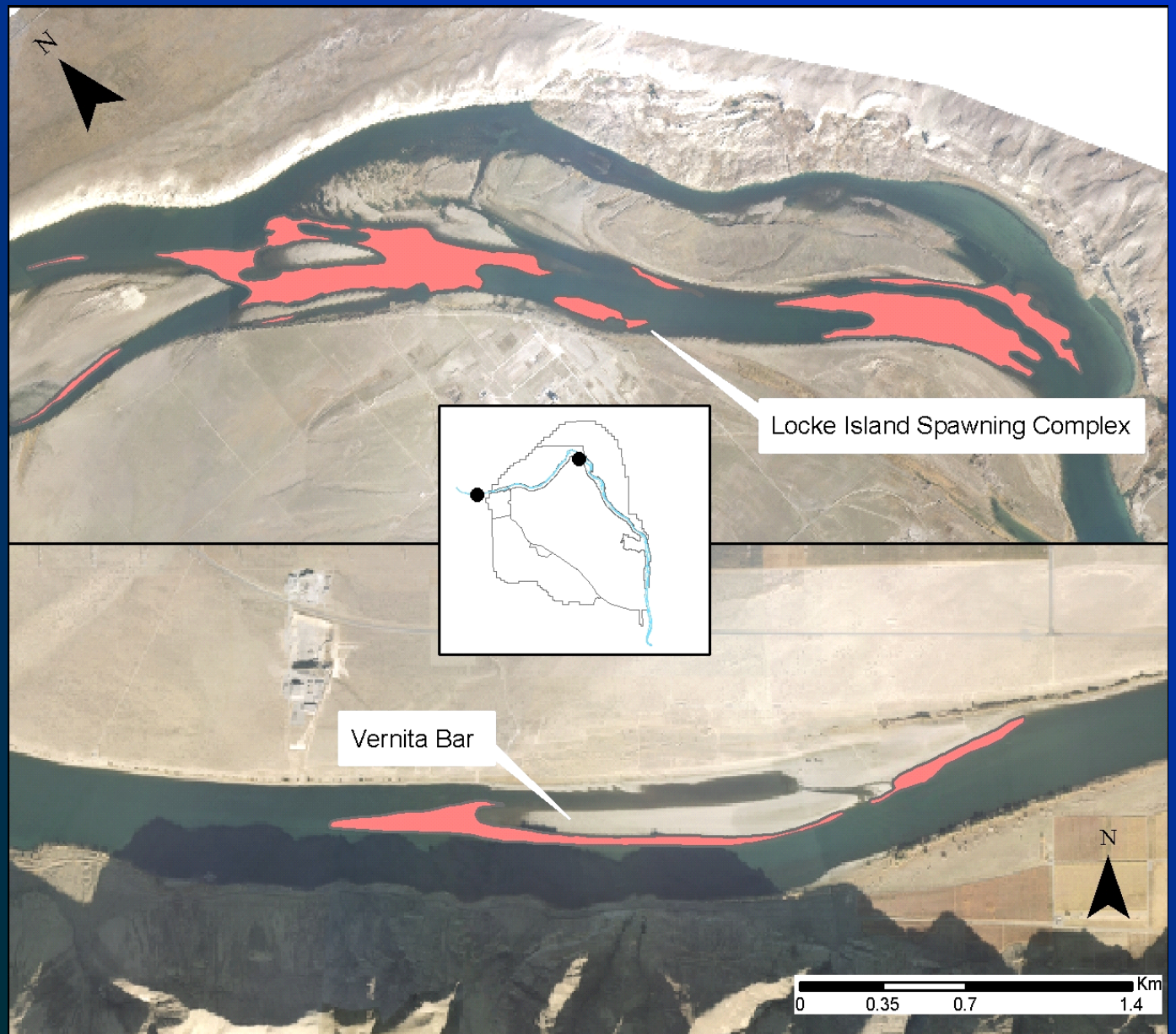


Water Management Issues
Fall Chinook Spawning

- Streamflows during spawning are not managed for anticipated escapement levels
- Spawning potential is limited as a function of water supply and anticipated power operations for the winter season
- Fluctuating flows influence spawning habitat

Water Management Issues
Fall Chinook Spawning

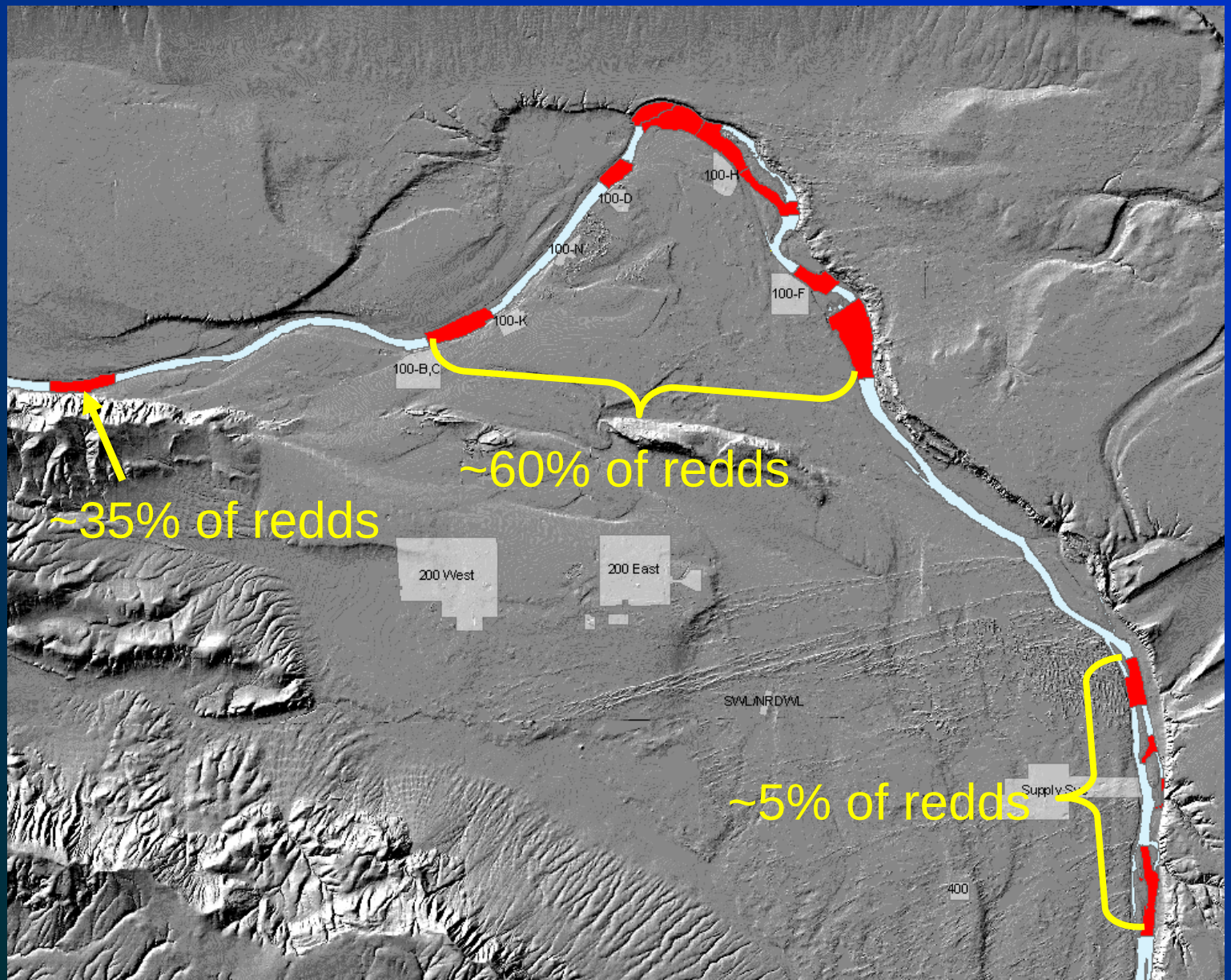
- Effects vary as a function of channel morphology and hydrograph variation



Water Management Issues

Fall Chinook Spawning

- **Spawning potential is currently managed based on a small portion of the Reach**



Management Needs and Goals

- **Develop a quantitative understanding of the effect of water management decisions on spawning habitat and productivity relative to Hanford Reach potential**
- **Develop a quantitative understanding of the effect of water management and flow fluctuations on mortality of juveniles**
- **Optimize spawning habitat availability throughout the Hanford Reach within the framework of annual water supply conditions**
- **Minimize the mortality of juveniles during the spring rearing period**
- **Optimize production for the largest mainstem Columbia River naturally spawning fall Chinook salmon population**

Hanford Reach Study Goals Entrapment/Stranding

Goal: Quantify the impacts of flow fluctuations on rearing juvenile fall Chinook and develop alternatives to help minimize impacts

- Quantify Impacts
- Identify factors leading to entrapment
- Explore operational alternatives to reduce impacts

Hanford Reach Study Goals

Goal: Quantify spawning and rearing habitat at various flows

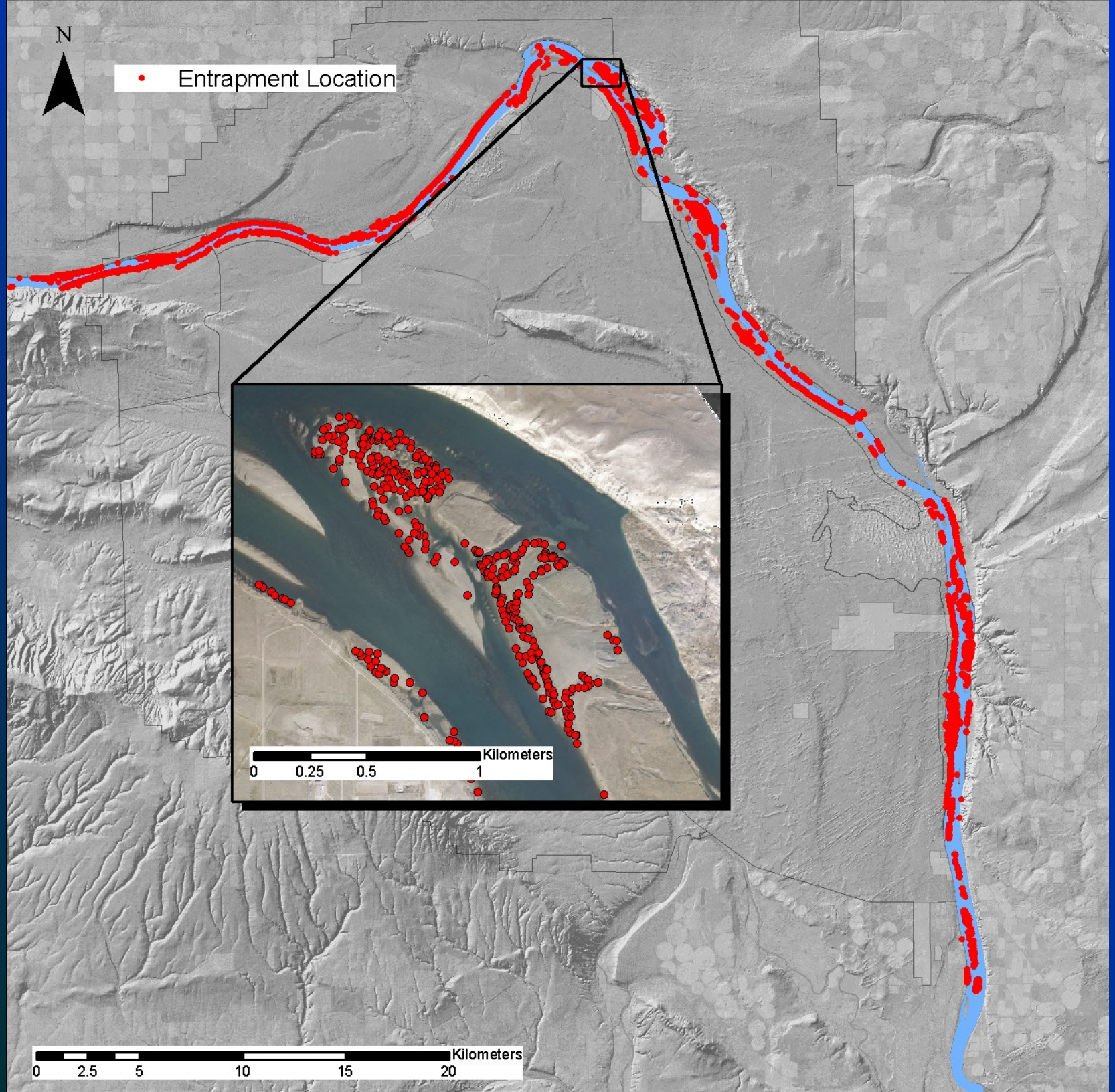
- Examine distribution of spawning and rearing habitat
- Quantify spawning and rearing habitat
- Estimate spawning habitat needed to accommodate various escapement targets
- Relationship between rearing habitat and entrapment results

Entrapment/Stranding Evaluation

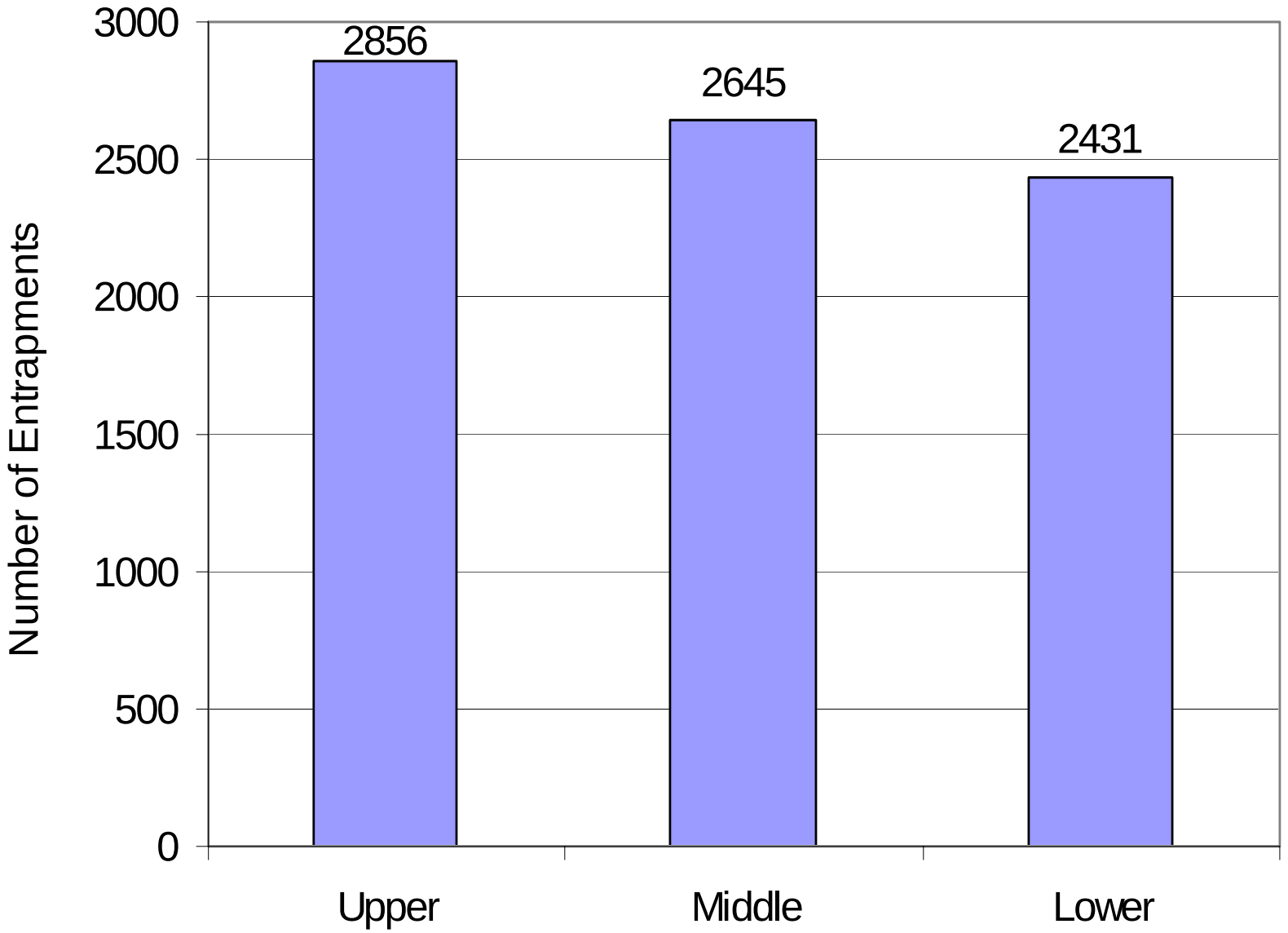
- Entrapment enumeration
- Entrapment fish sampling
- Entrapment impact estimates
- Determining population-level impacts
- Effects of alternative hydro operations
- Dampening flow fluctuations

Enumerating Entrapments

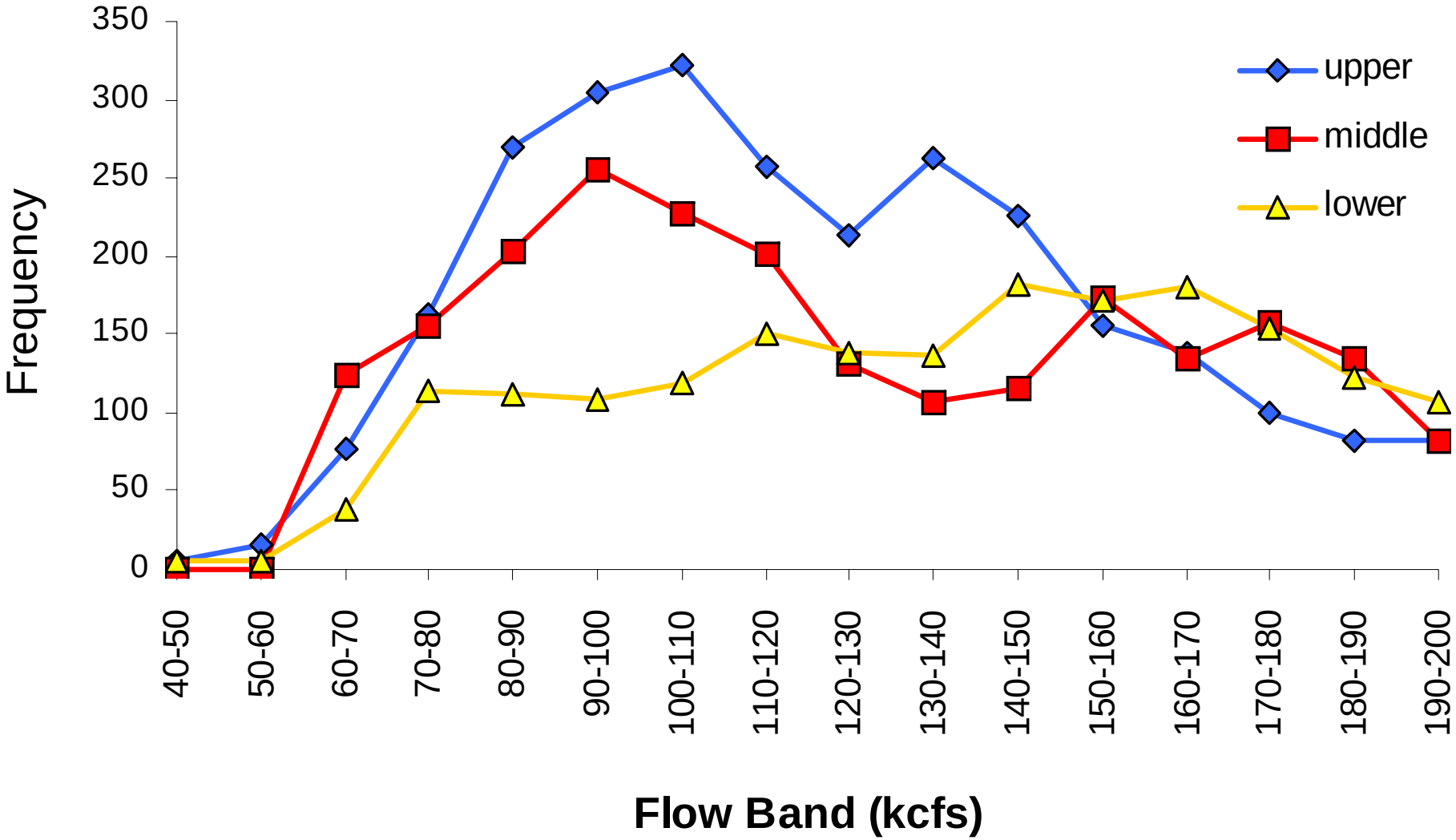
Upstream Tip of Locke Island


N
Entrapment Location
Kilometers
0 0.25 0.5 1
Kilometers
0 2.5 5 10 15 20

Entrapment numbers by river segment

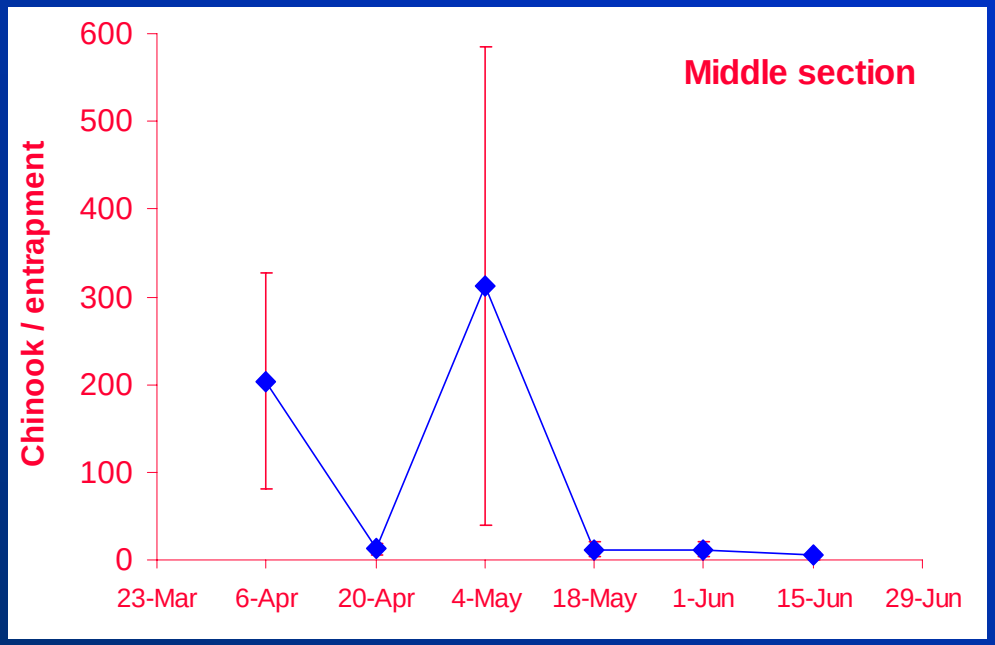


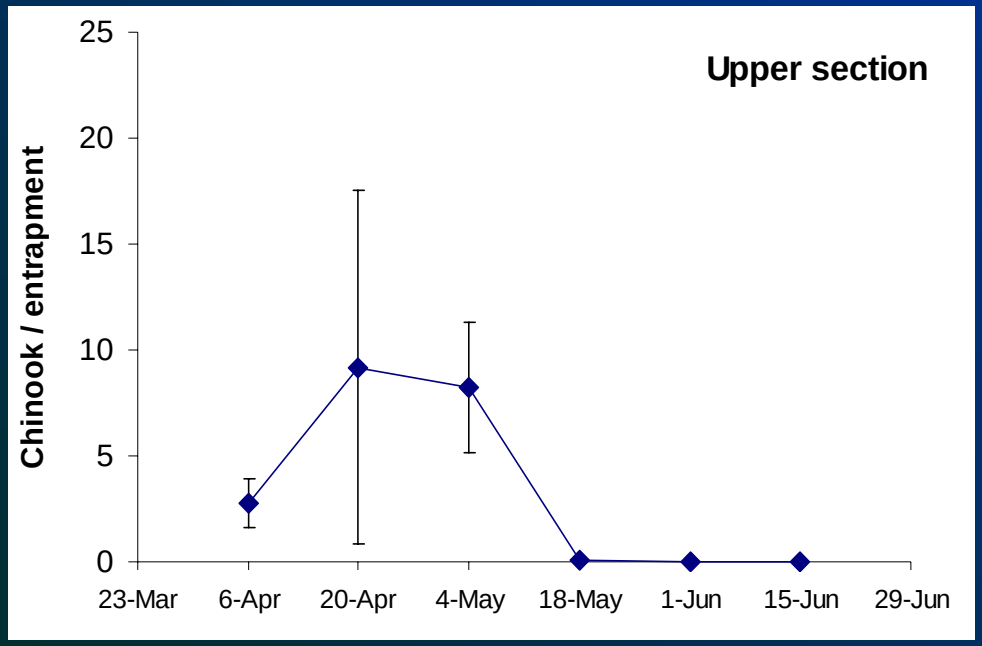
Entrapment distribution by river segment

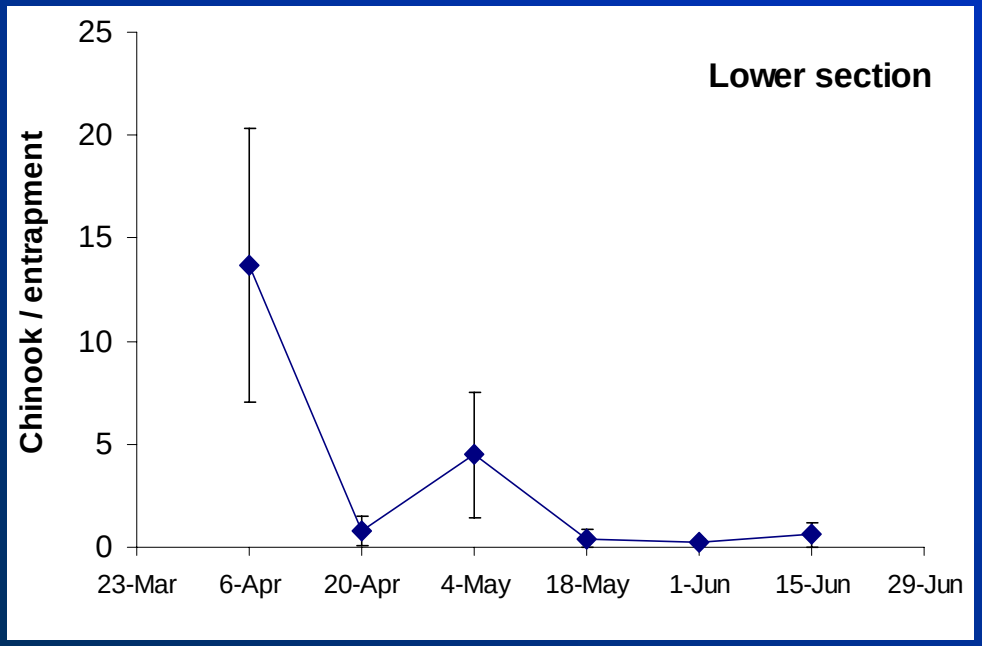


Fish Sampling

Chinook per entrapment by section and sampling period:







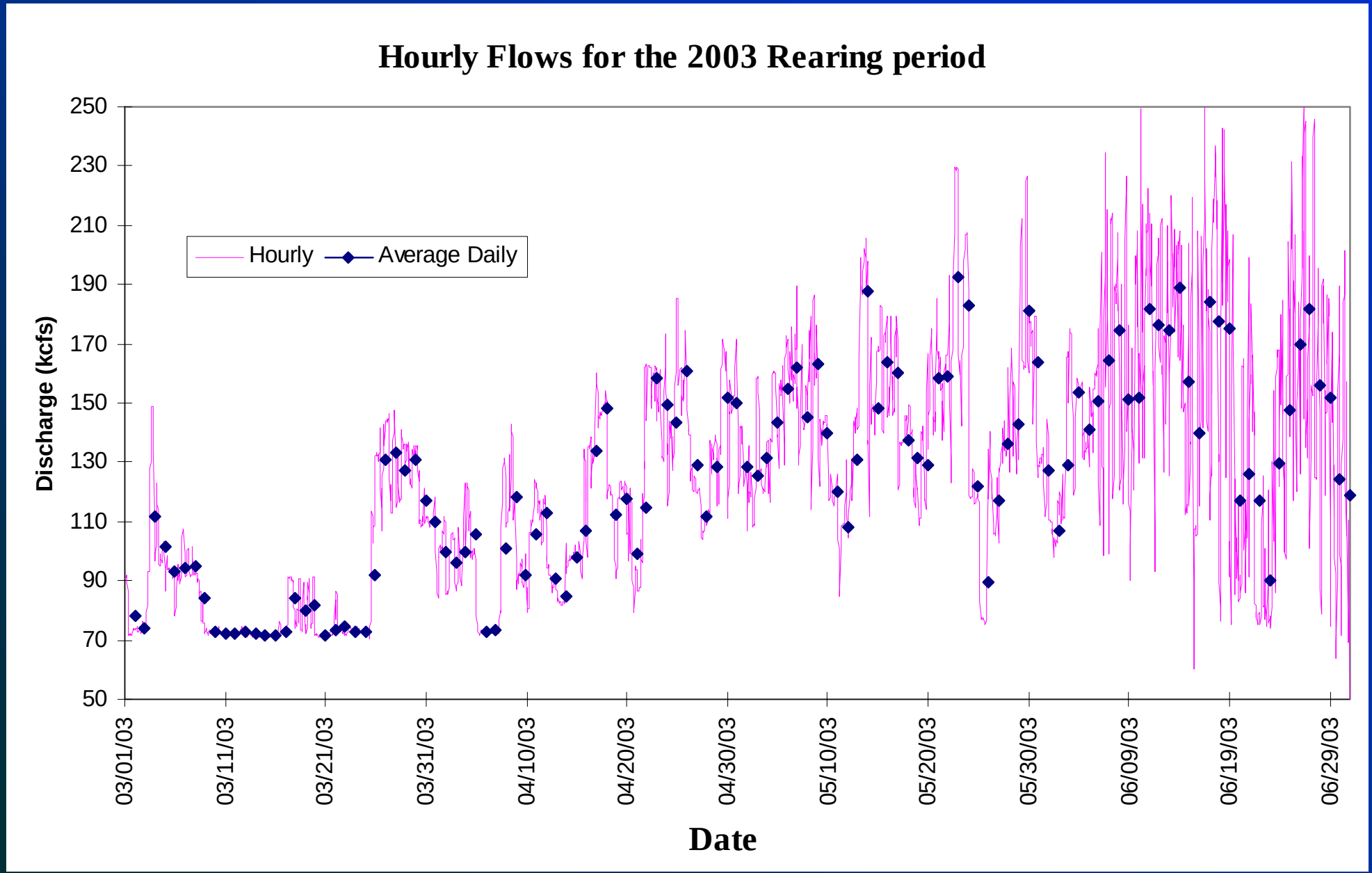
Fates of Entrapped Fish

- 82% mortality
  - 59% of the mortalities due to draining
  - 41% of the mortalities due to water temperature

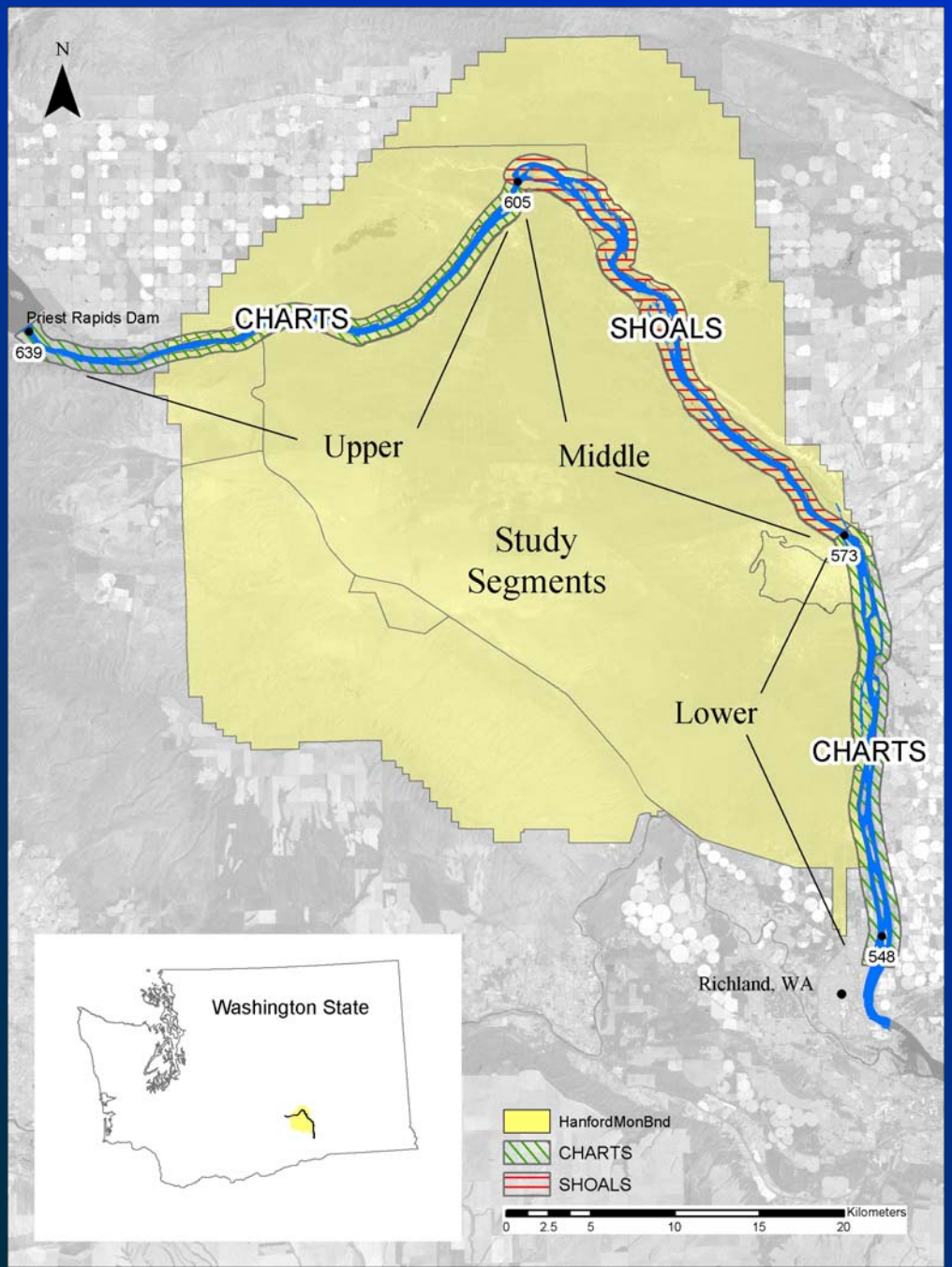
Entrapment Impact - Approach

- Field identification and geographic location of entrapments.
- 1-D steady state hydrodynamic modeling for flows ranging from 30-400 kcfs in 10 kcfs increments-shorelines.
- 1-D unsteady state hydrodynamic modeling to route hourly hydrograph from Priest Rapids through Reach.
- Creation of entrapment event history.
- Integration of entrapment event history with temporal and spatial results of random field sampling for fish impacts.

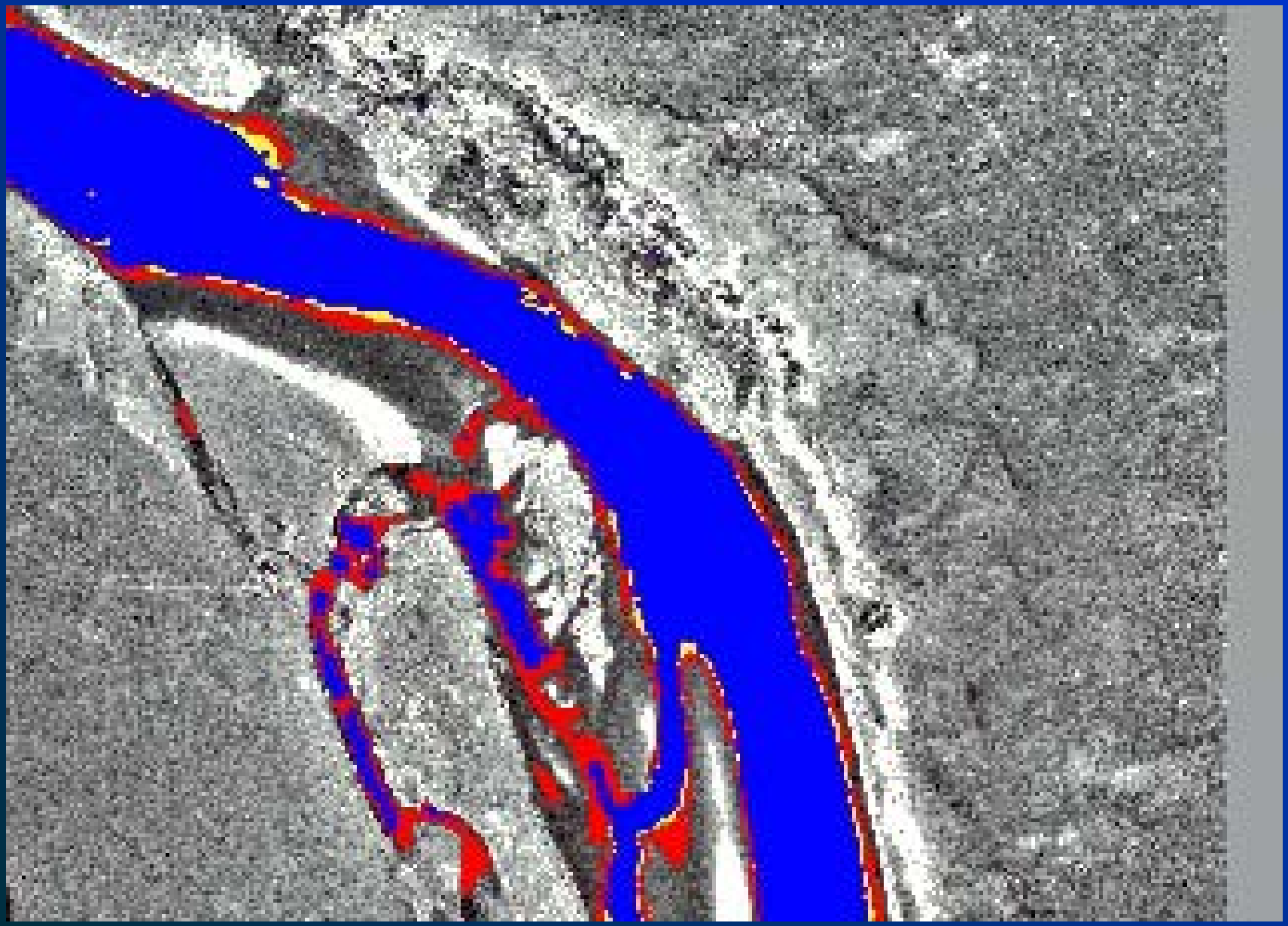
Priest Rapids Dam



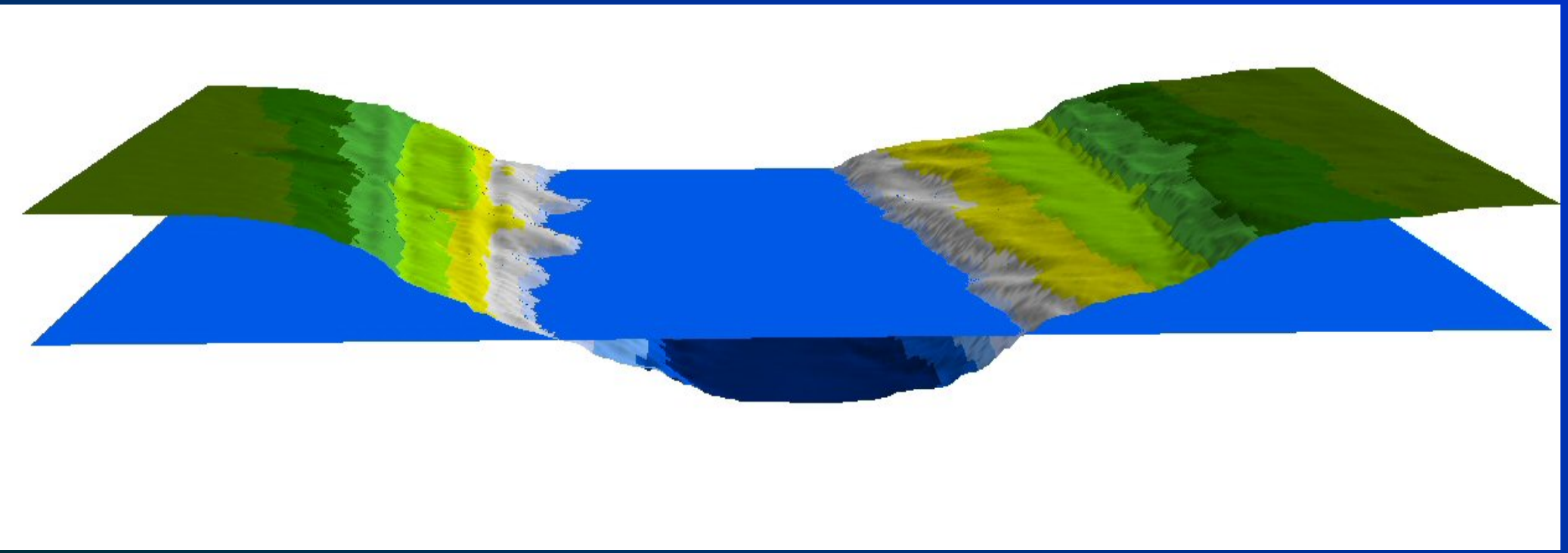
Location of the Upper, Middle and Lower study segments with CHARTS and SHOALS area of geographic coverage

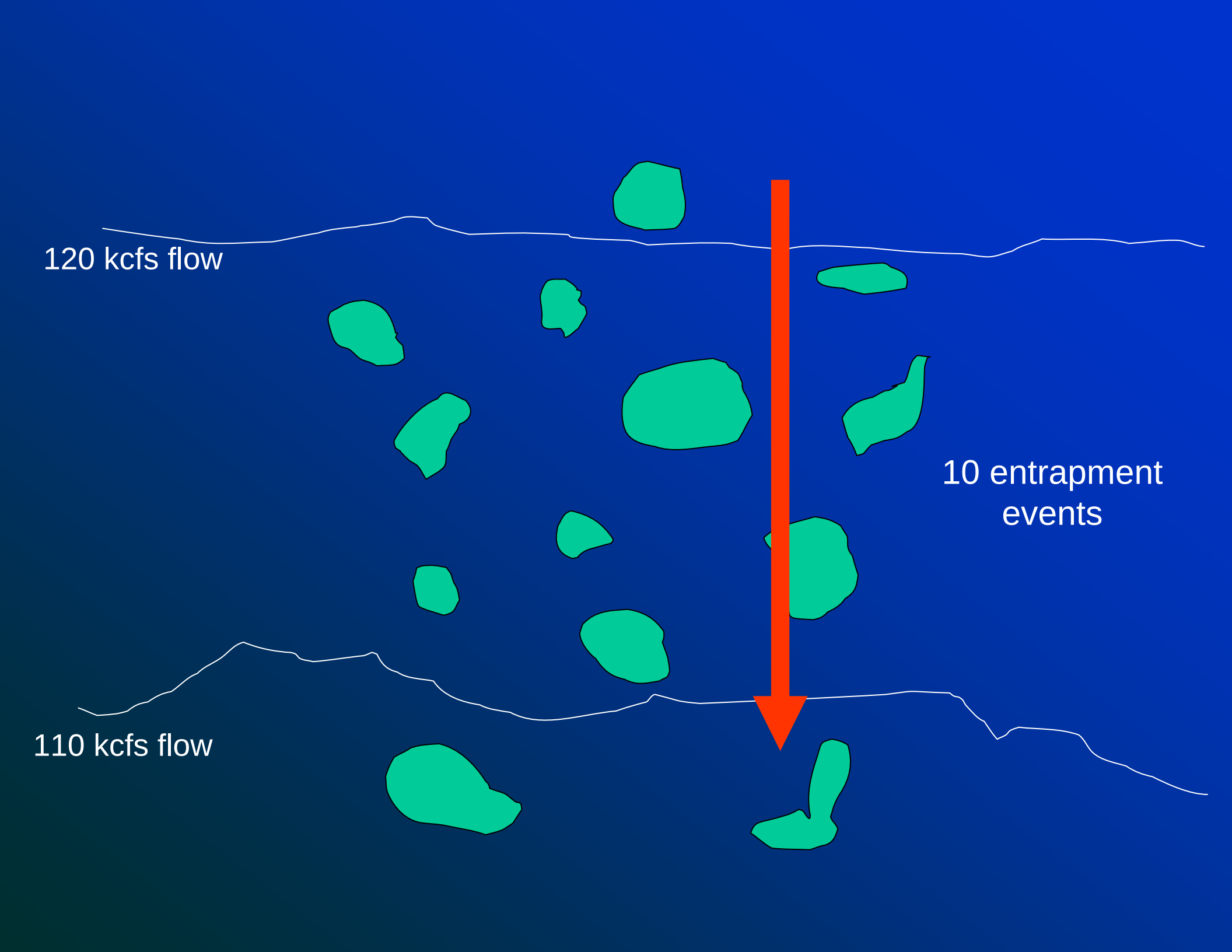


Simulated Flow and Habitat Changes

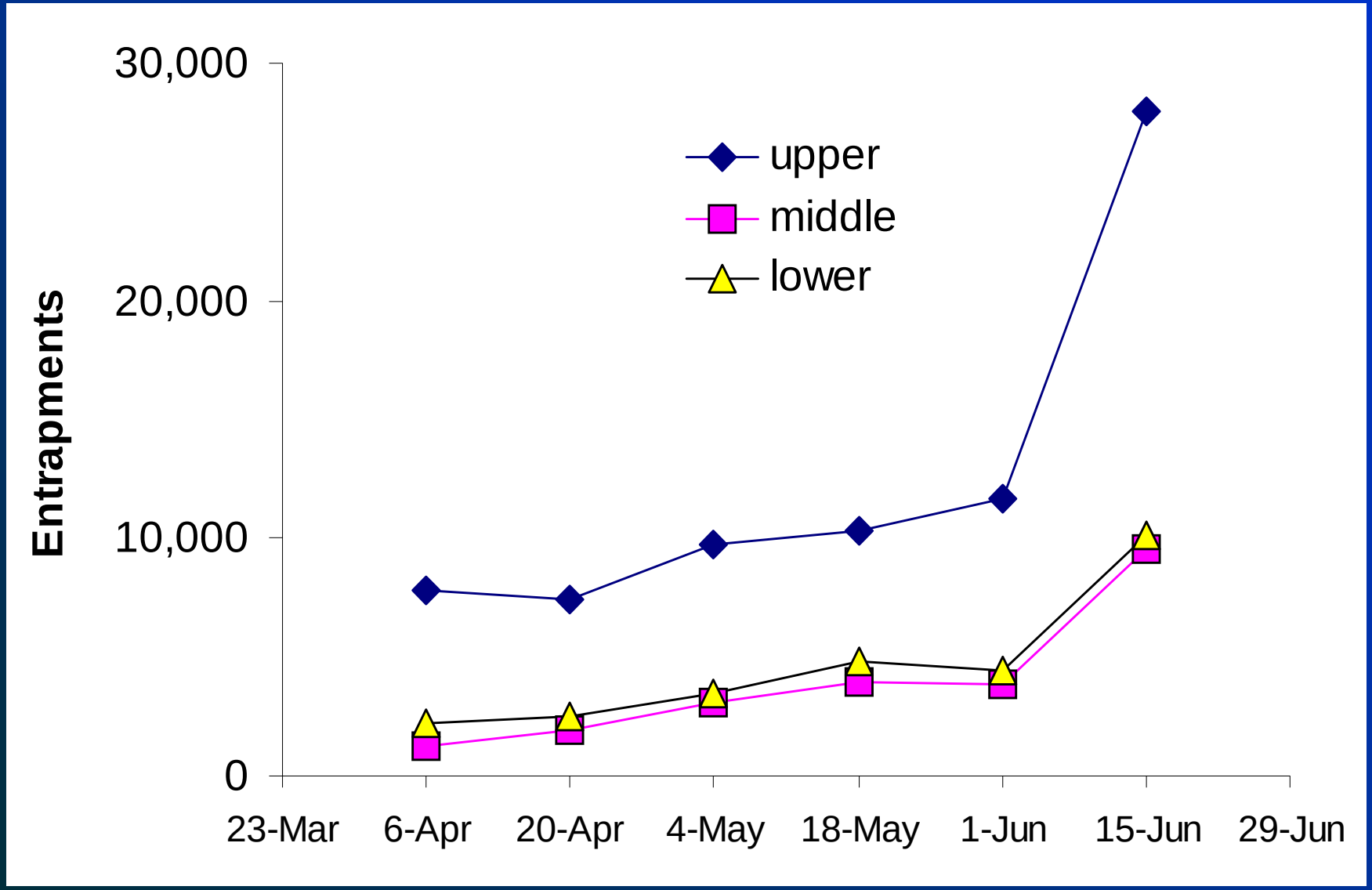


Modeling Flow Bands

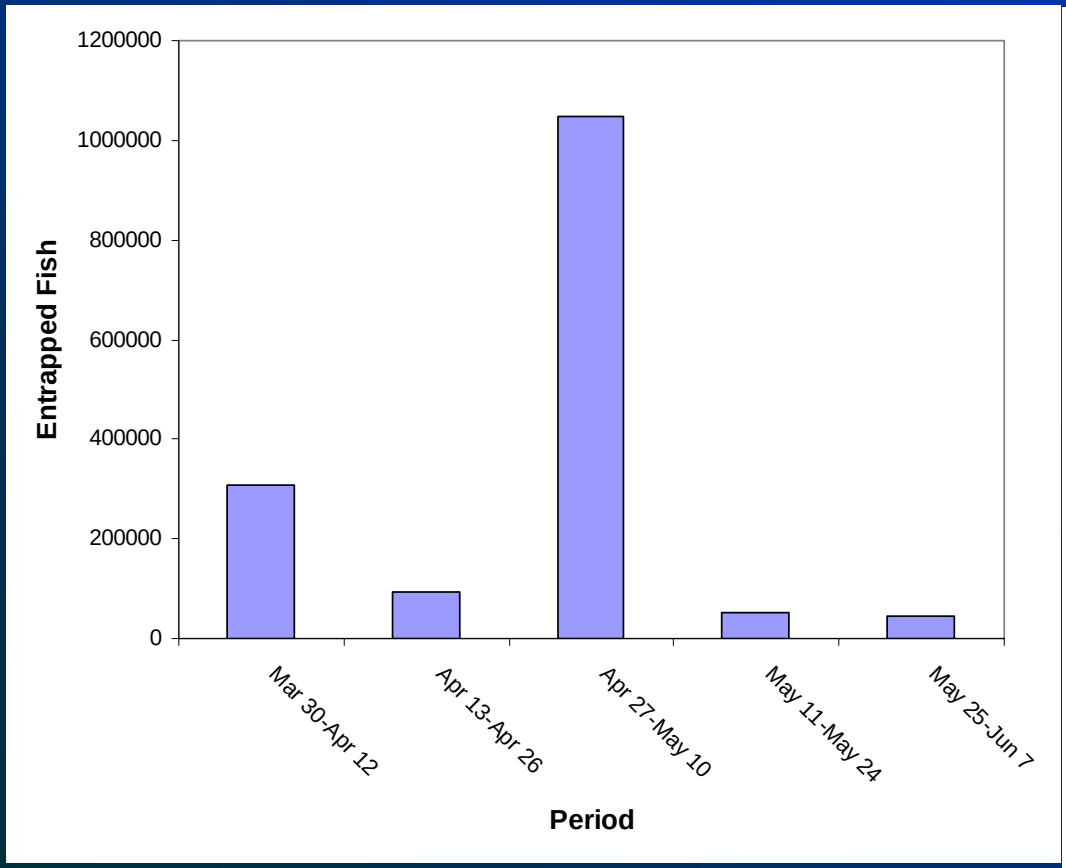


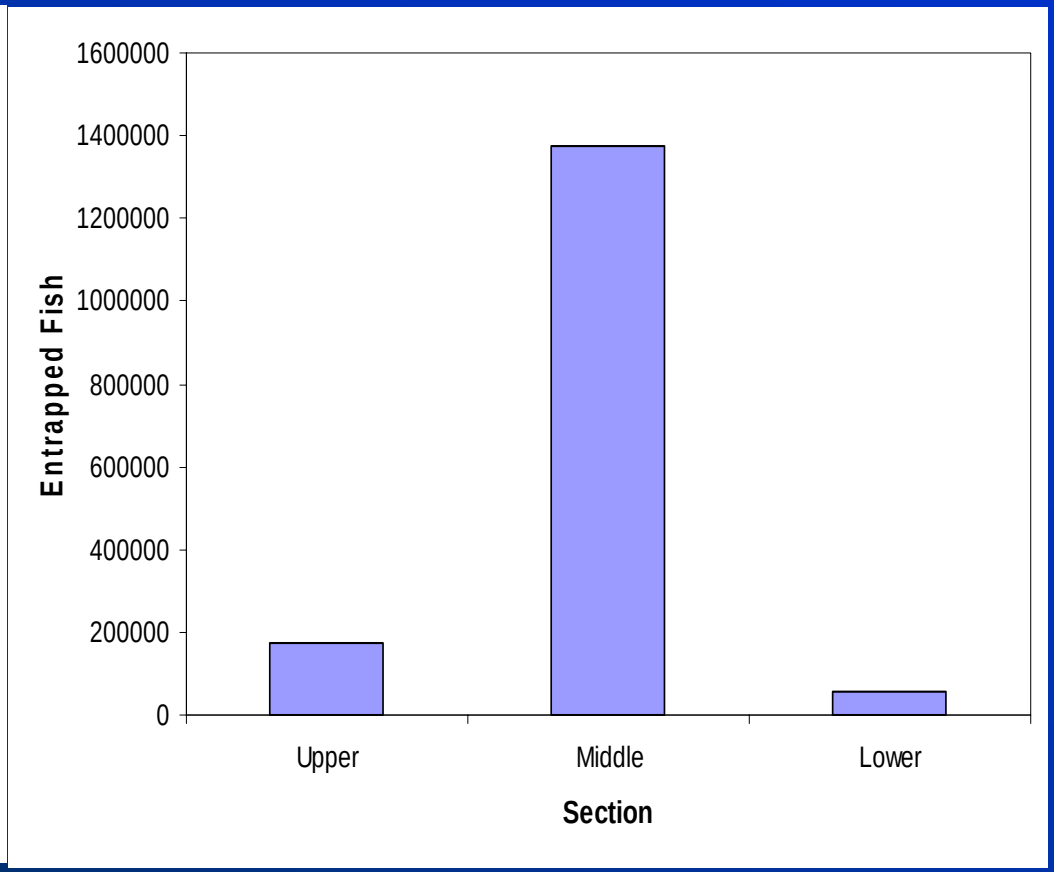

120 kcfs flow
10 entrapment events
110 kcfs flow

Number of entrapments events by section and sampling period



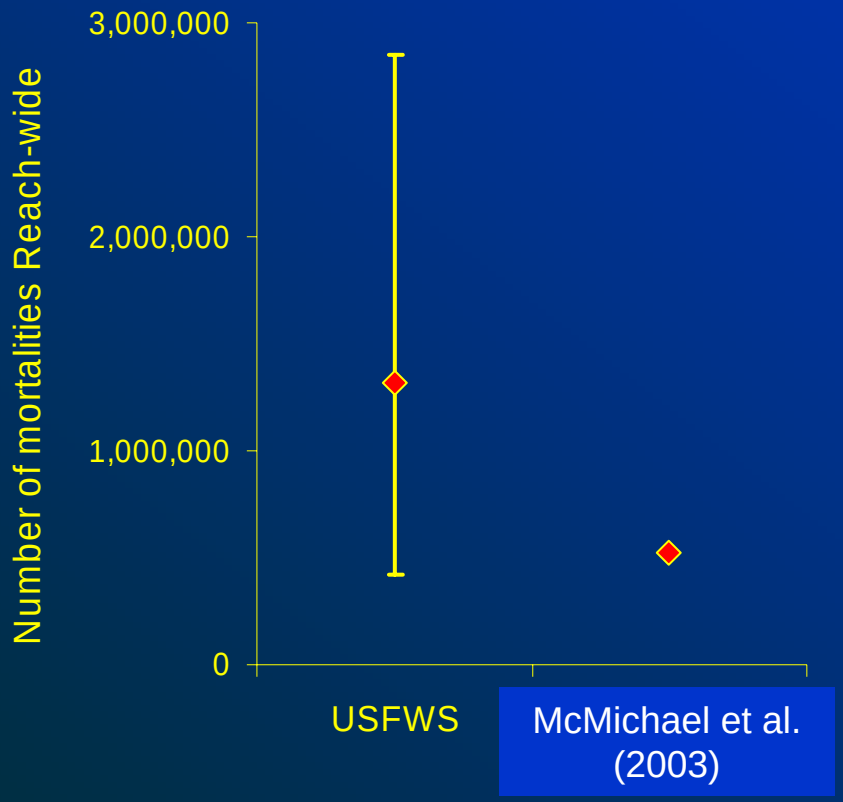
Entrapped Fish



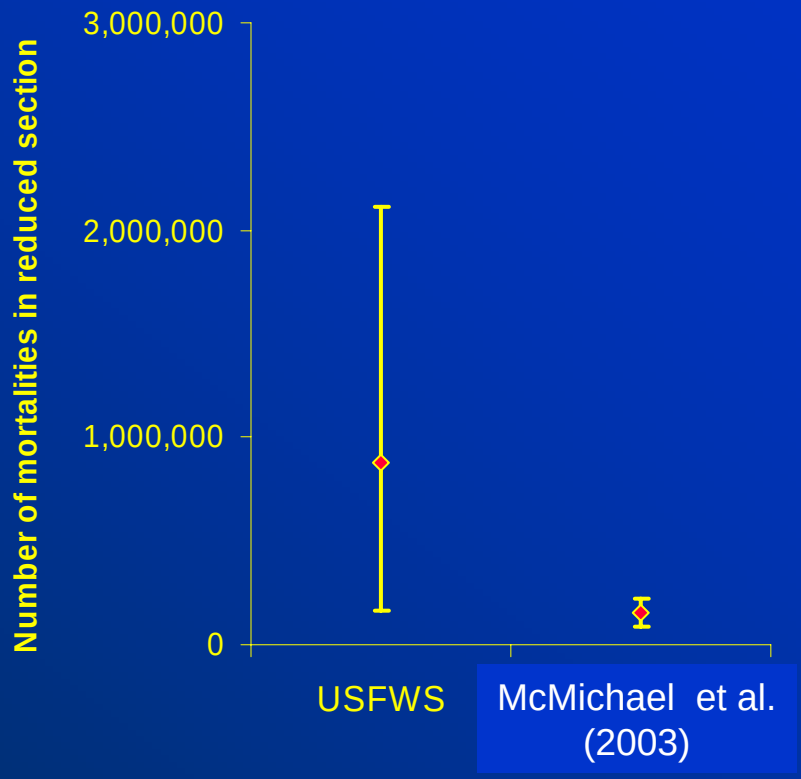


2003 impact estimates

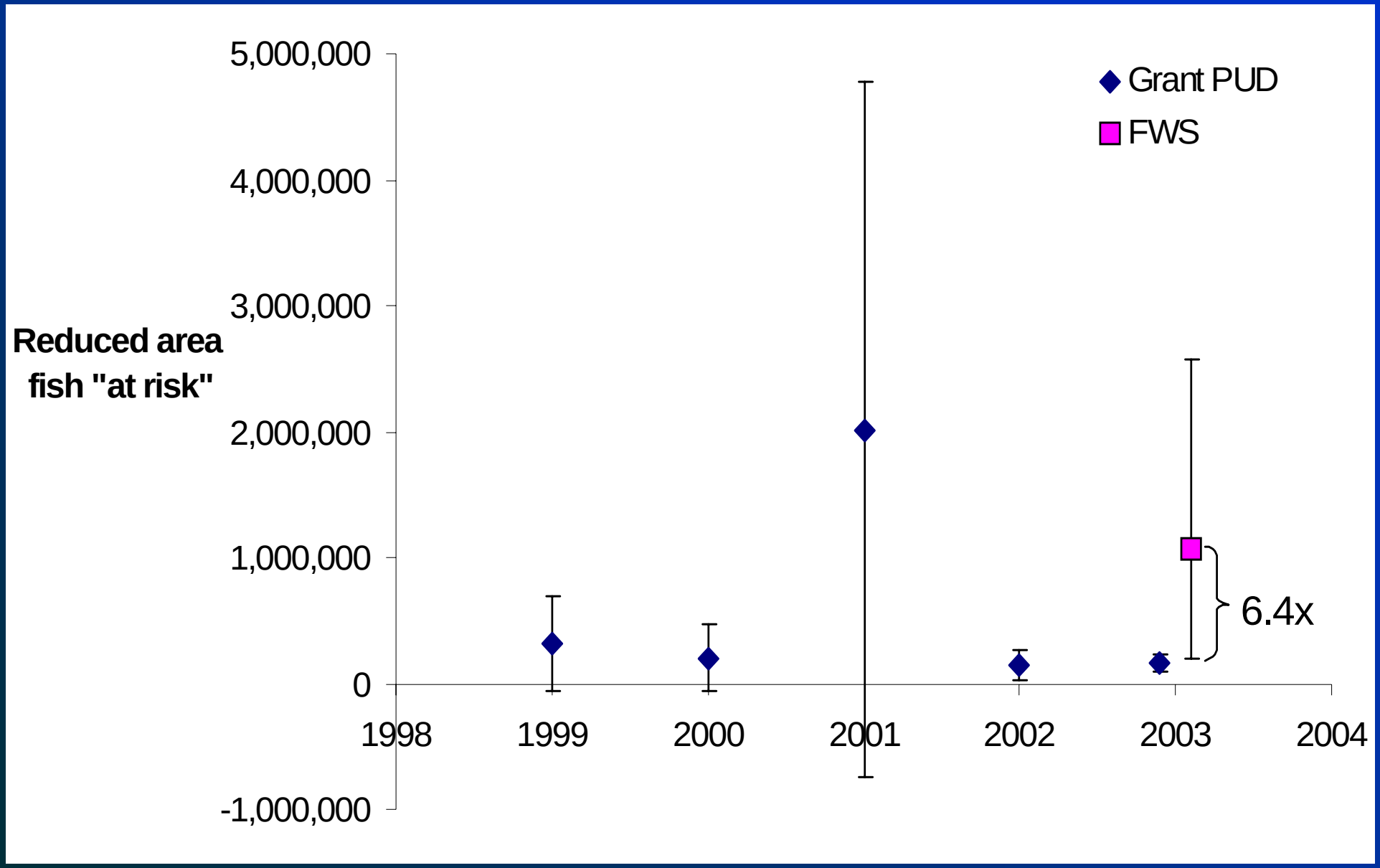
Reach-wide



9.8 mile sub-section



Reduced Area Impact Estimates 1999-2003



Population Level Impact Approaches

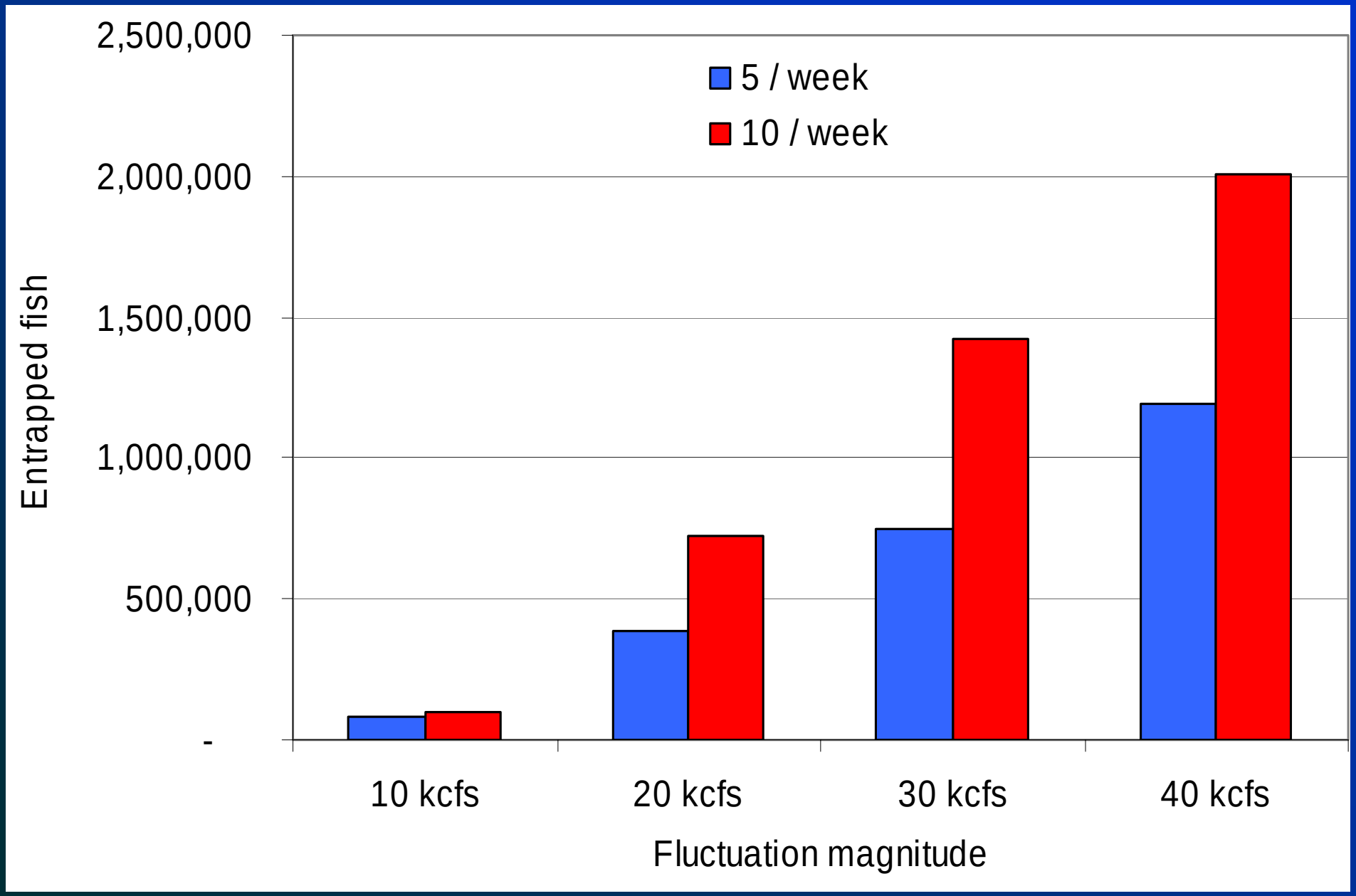
- SAR Approach – lost adults
  - Hatchery CWT
  - Wild CWT
- Fry Mortality Approach – fry mortality rate
  - Female Spawners
  - Fecundity
  - Egg-to-fry survival
  - Total Fry
- Lost Harvest Opportunity – adults
  - Fry mortality rate
  - Pacific Salmon Commission Chinook Model

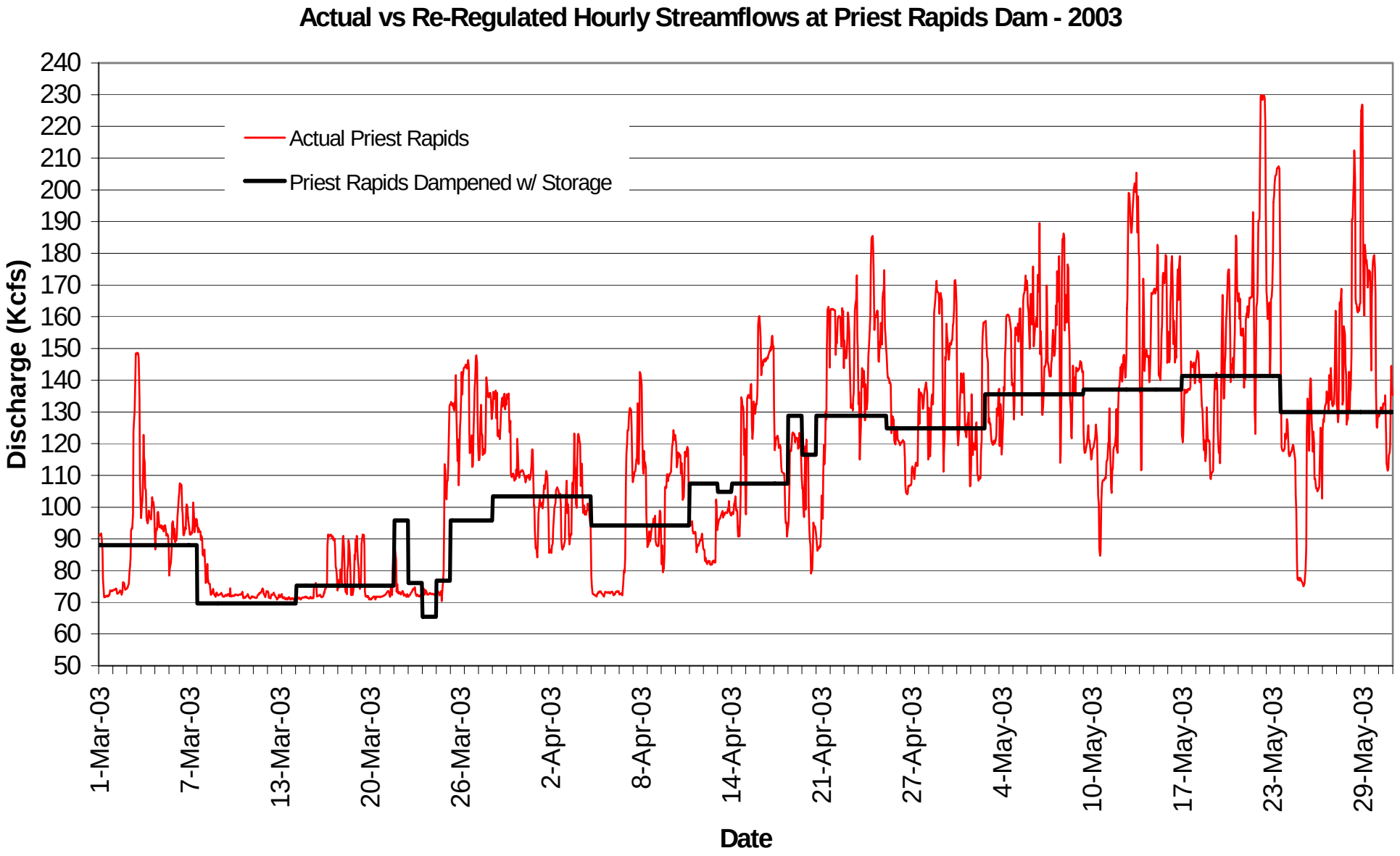
Population Level Impact Results

- SAR Approach
  - 4,300 to 12,900 adults
- Fry Mortality
  - 12% average mortality rate (4% to 31% range) for 2003
  - 74% average mortality rate (31% to 90% range) for 2001
- Lost Harvest Opportunity

Fry Reduction	Catch Reduction
5%	9,000
25%	42,000
50%	170,000

Evaluation of Alternative Operations




Actual vs Re-Regulated Hourly Streamflows at Priest Rapids Dam - 2003
Actual Priest Rapids
Priest Rapids Dampened w/ Storage
Discharge (Kcfs)
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
1-Mar-03
7-Mar-03
13-Mar-03
20-Mar-03
26-Mar-03
2-Apr-03
8-Apr-03
14-Apr-03
21-Apr-03
27-Apr-03
4-May-03
10-May-03
17-May-03
23-May-03
29-May-03
Date

Reregulation Success Rate

Year	Number of Days Storage Capacity Exceeded	% of Days Average Weekly Flow Target Met
1995	3	96.7
1996	1	98.9
1997	7	92.4
1998	13	85.9
1999	2	97.8
2000	0	100.0
2001	1	98.9
2002	4	95.7
2003	5	94.6
2004	0	100.0

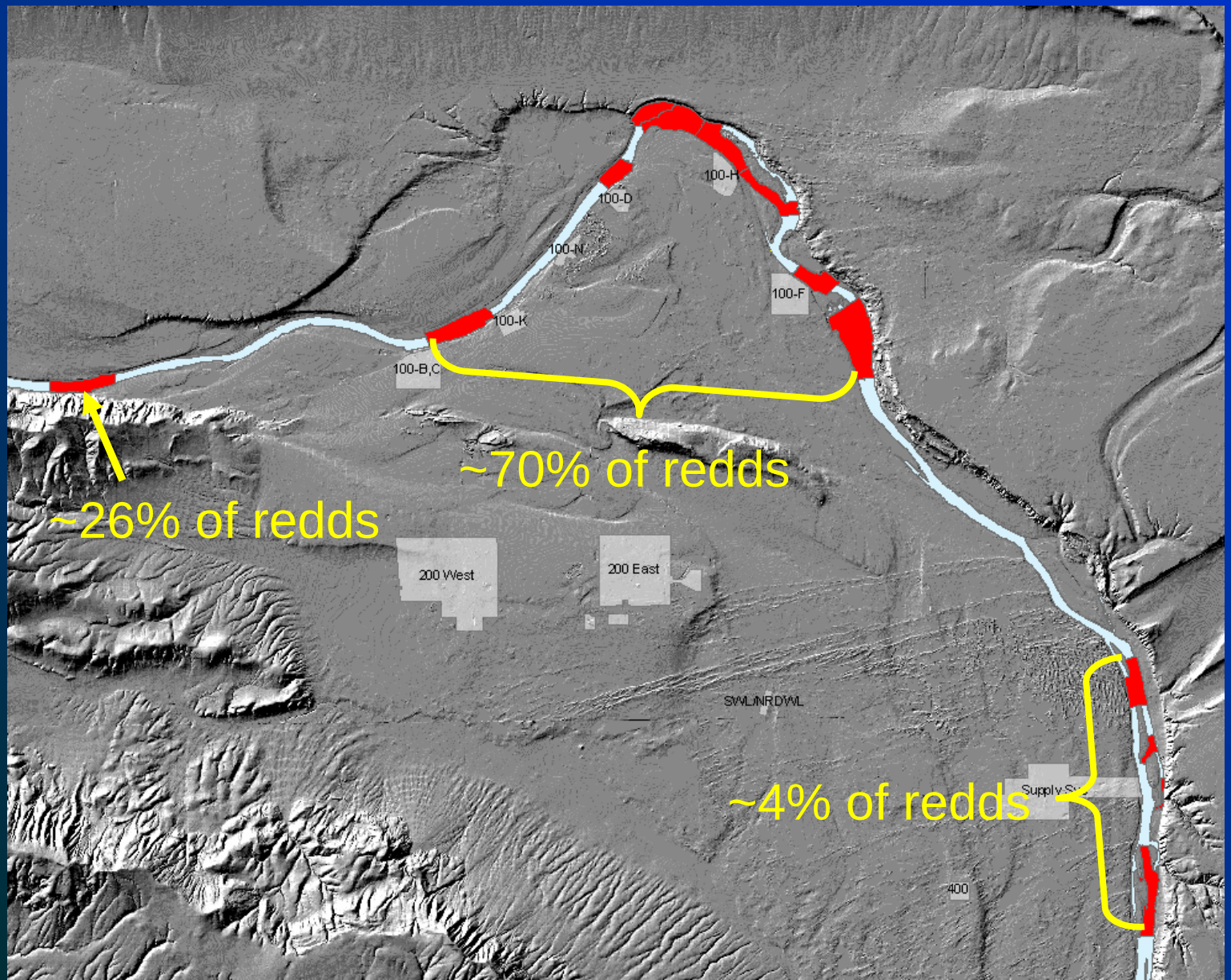
Entrapment Evaluation Summary

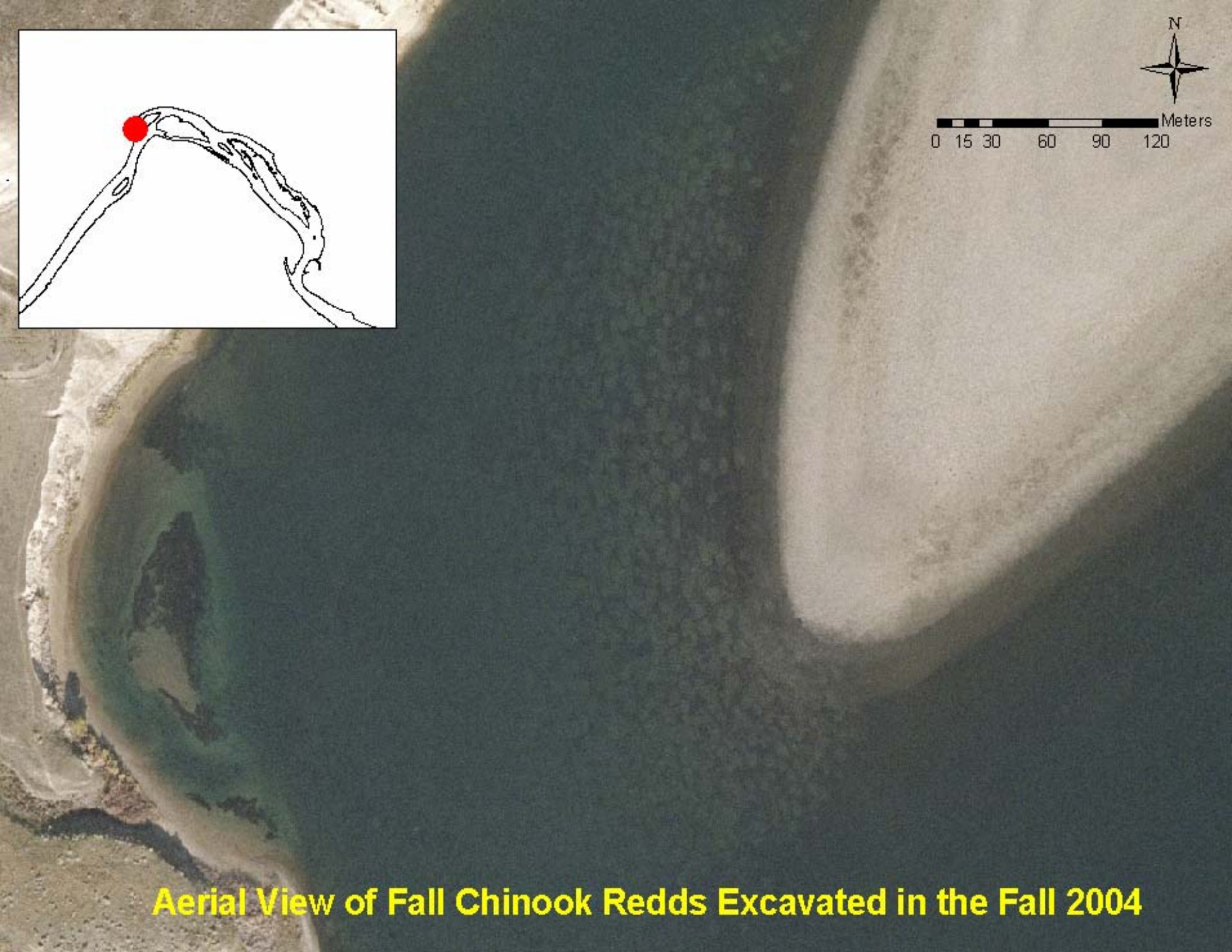
- A Reach-wide, geospatial quantitative assessment is complete for providing the physical framework to evaluate the effect of flows and flow fluctuations on juvenile mortality.
- A Reach-wide juvenile Chinook mortality estimate has been developed for spring of 2003 that provides a more comprehensive, robust evaluation of the impact of flow fluctuations.
- Results suggest that fluctuation magnitude is the primary driver of impacts; flow levels are less influential.
- Evaluation of operational alternatives is now possible to provide guidelines for flow fluctuations that will reduce the level of mortality on rearing fall Chinook.

Spawning Habitat Evaluation

- Spawning distribution
- Spawning habitat characteristics
- Spawning habitat model
- Spawning habitat simulations
- Spawning habitat and escapement

Spawning Distribution 2004



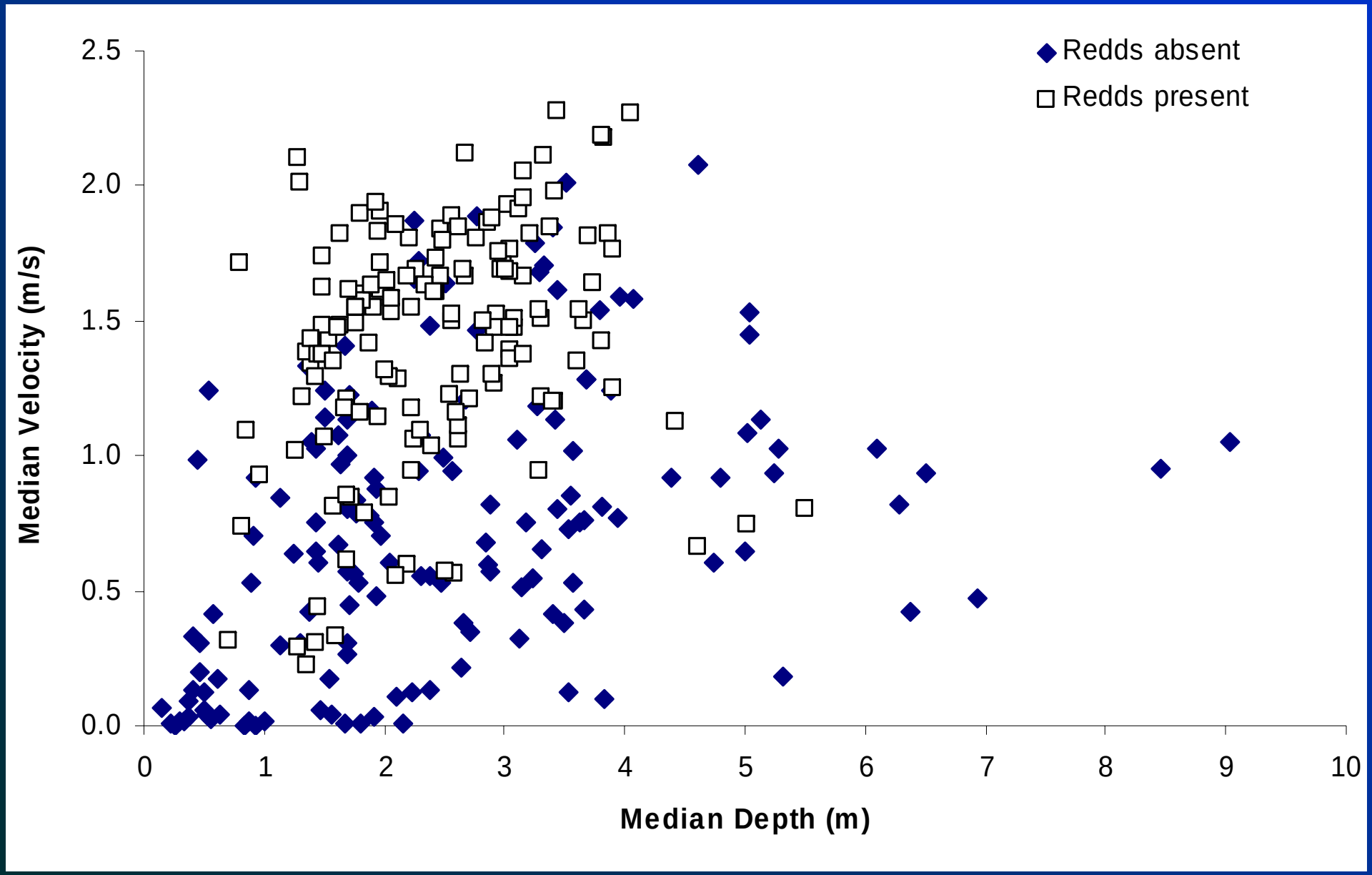


Aerial View of Fall Chinook Redds Excavated in the Fall 2004

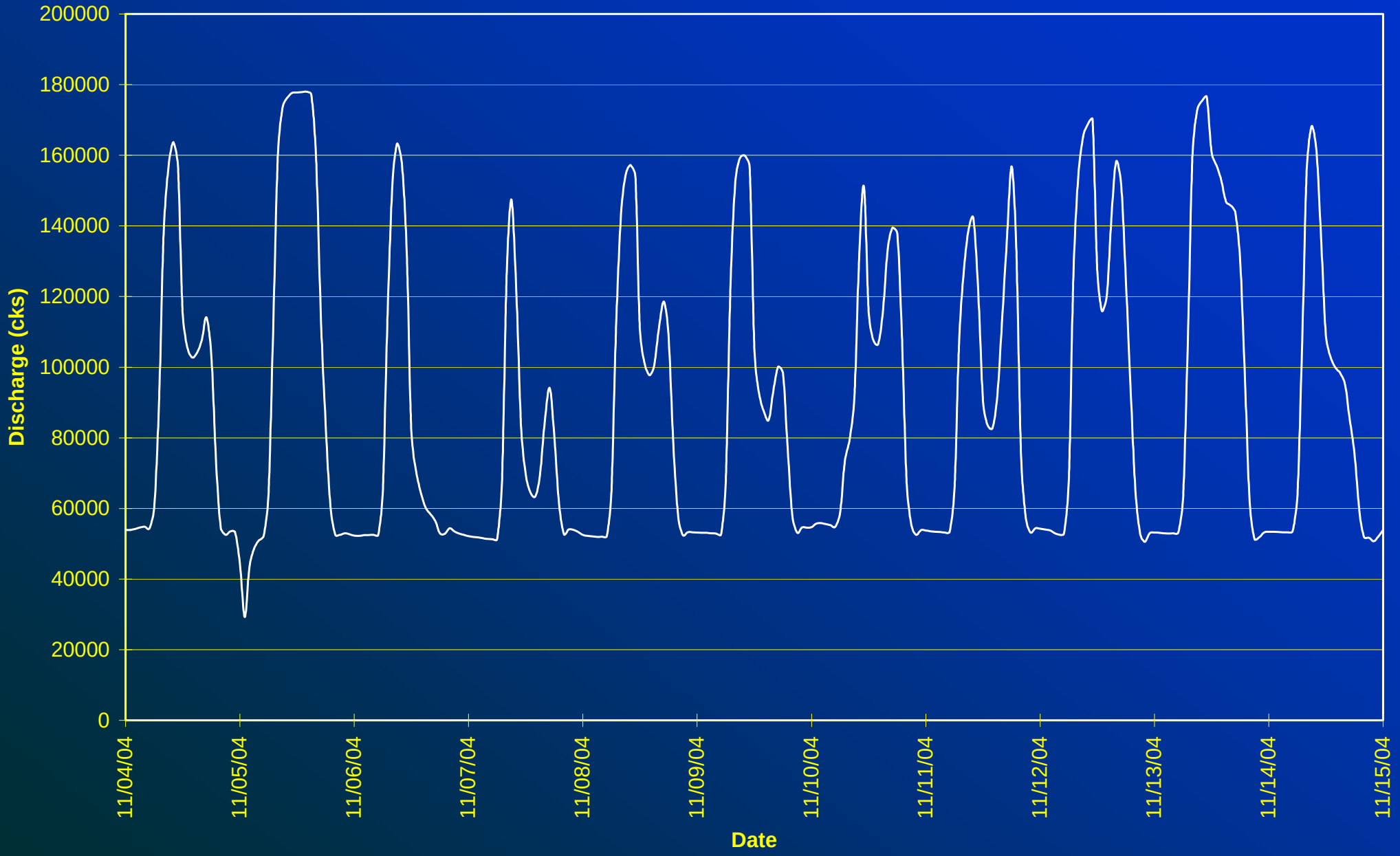
Spawning Habitat Characteristics

- Exploratory analysis in the middle section
- Evaluated characteristics for habitat with and without redds (35 characteristics)
  - Velocity
  - Persistence of a suitable velocity range
  - Depth
  - Slope

Locations with and without redds in the Locke Island Area

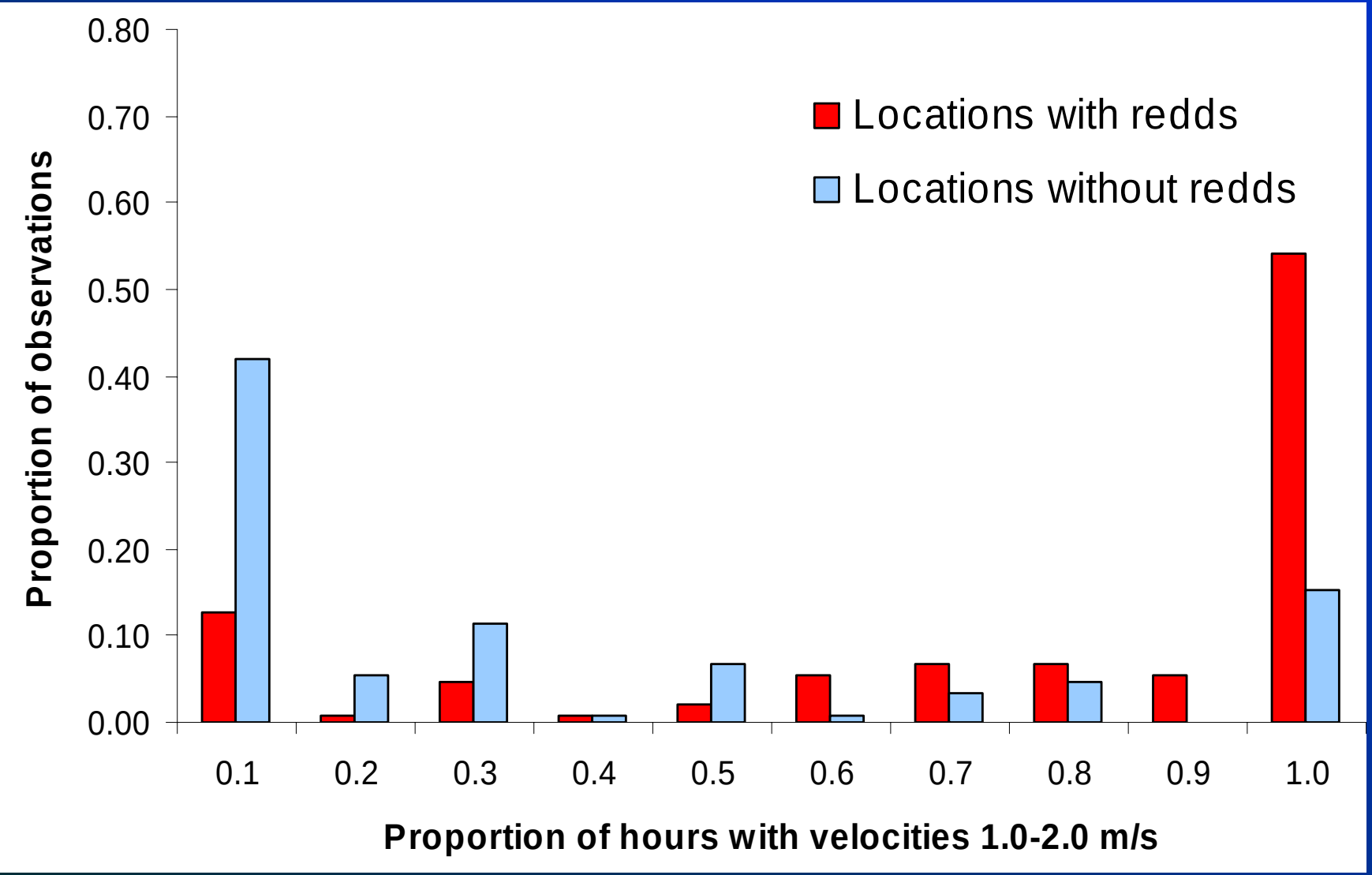


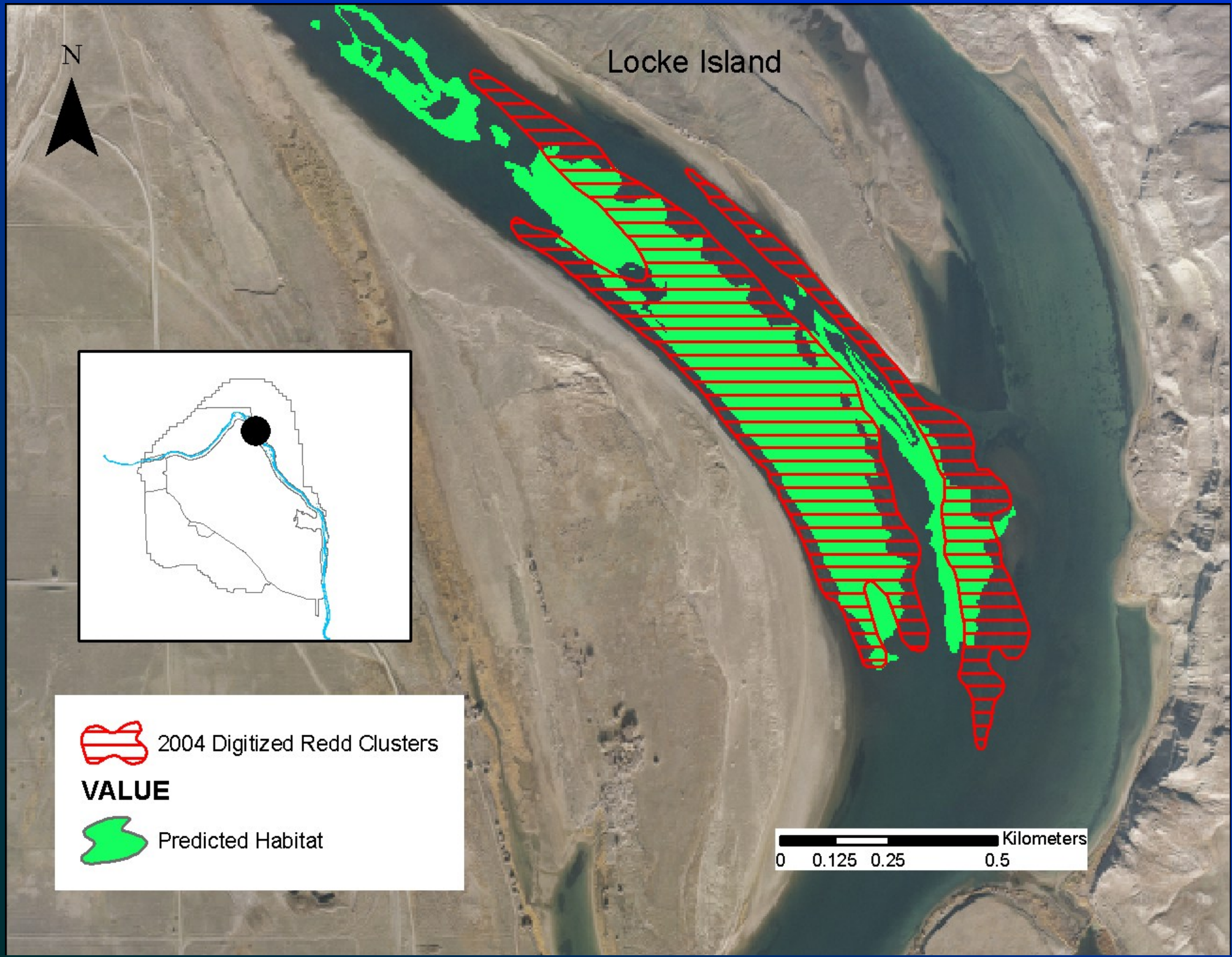
2004 Priest Rapids Dam Hydrograph



Spawning Habitat Model

- The persistence variable, based on the proportion of hours that velocities were between 1.0-2.0 m/s, provided the most explanatory ability

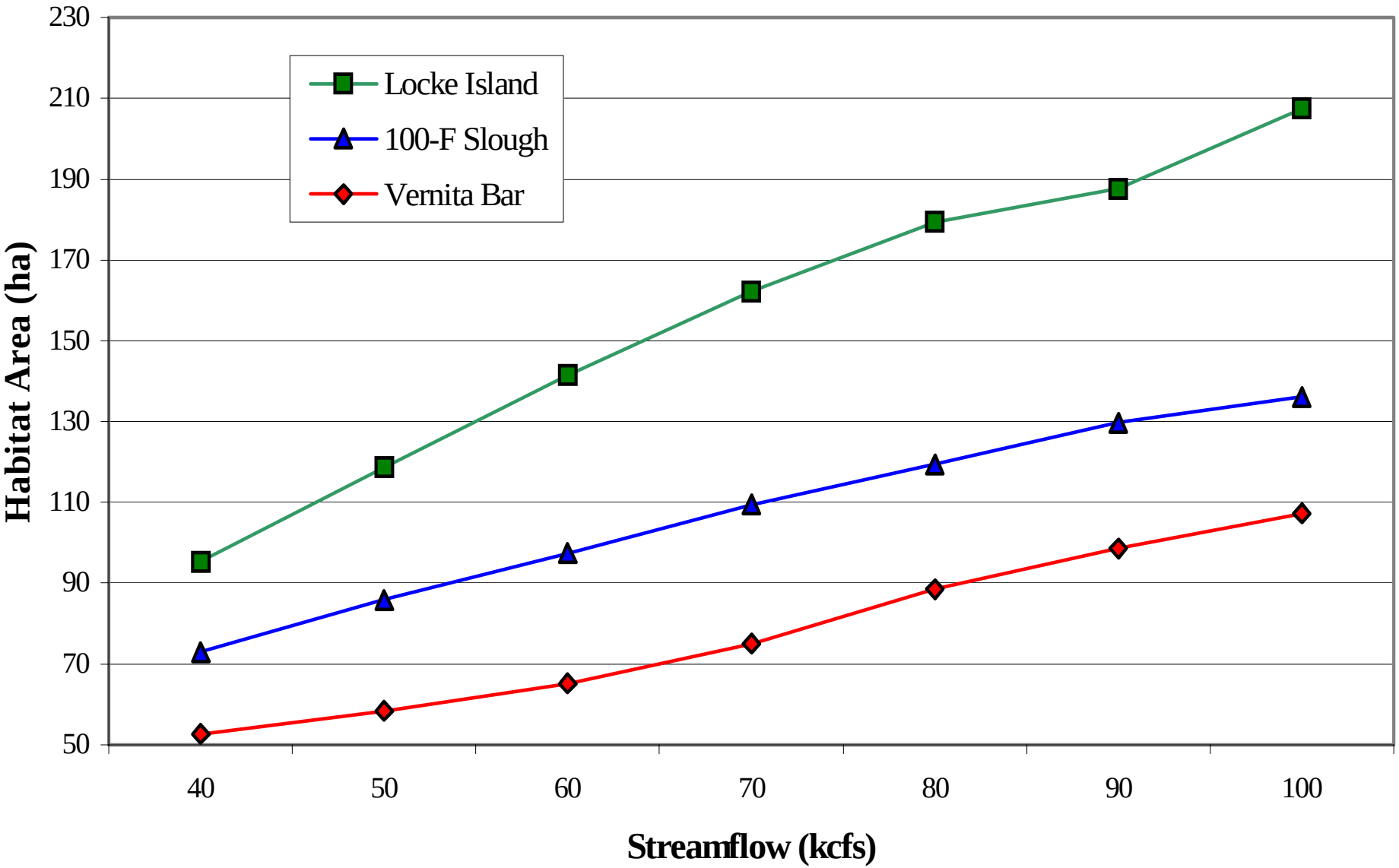



N
Locke Island
2004 Digitized Redd Clusters
VALUE
Predicted Habitat
Kilometers
0 0.125 0.25 0.5

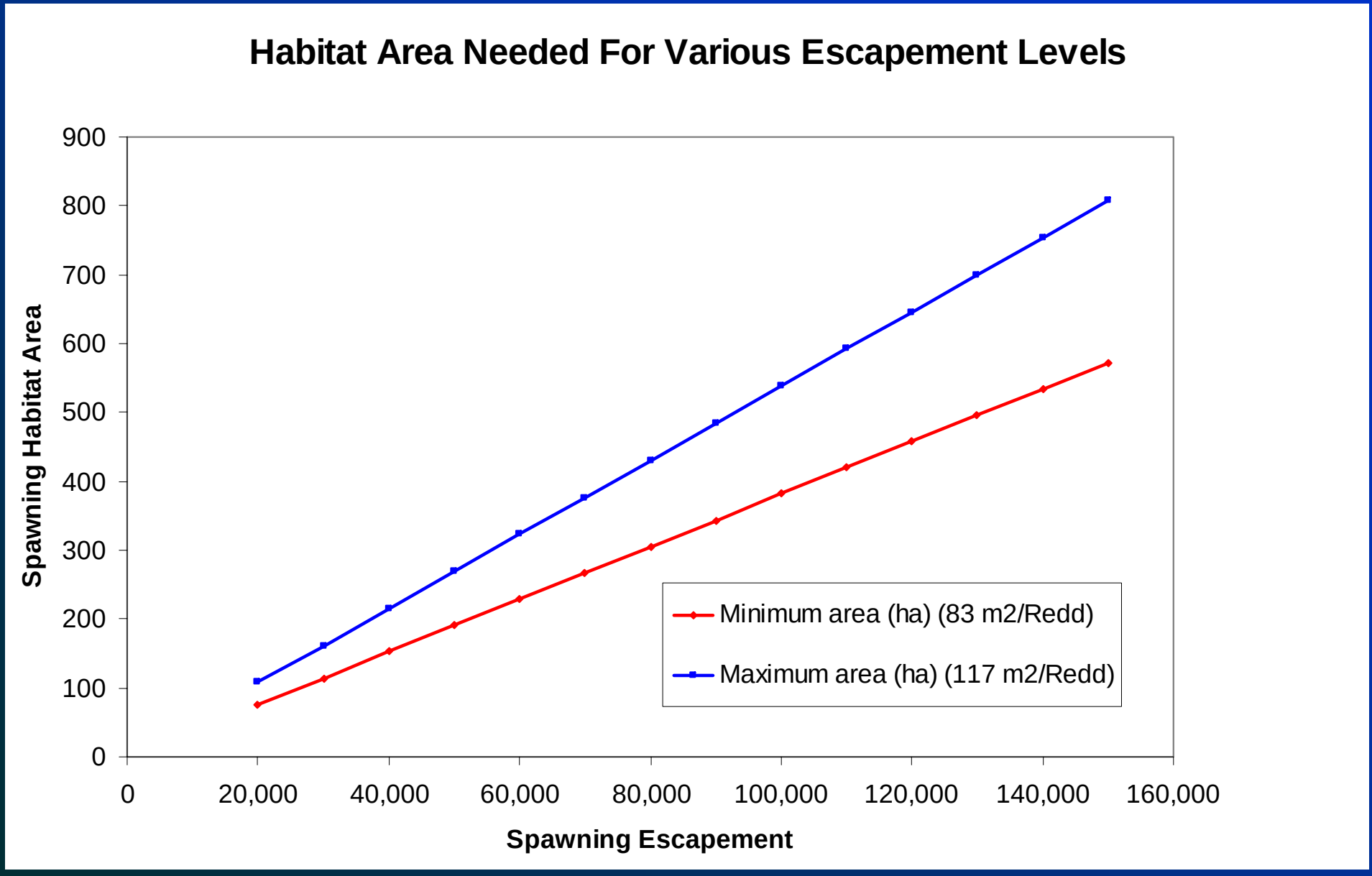
Spawning Habitat Simulations

- Comparison of available habitat at various steady state flows and locations
- Comparison of available habitat for alternative operations

Steady State Flow Habitat Simulations



Spawning Habitat and Escapement Levels

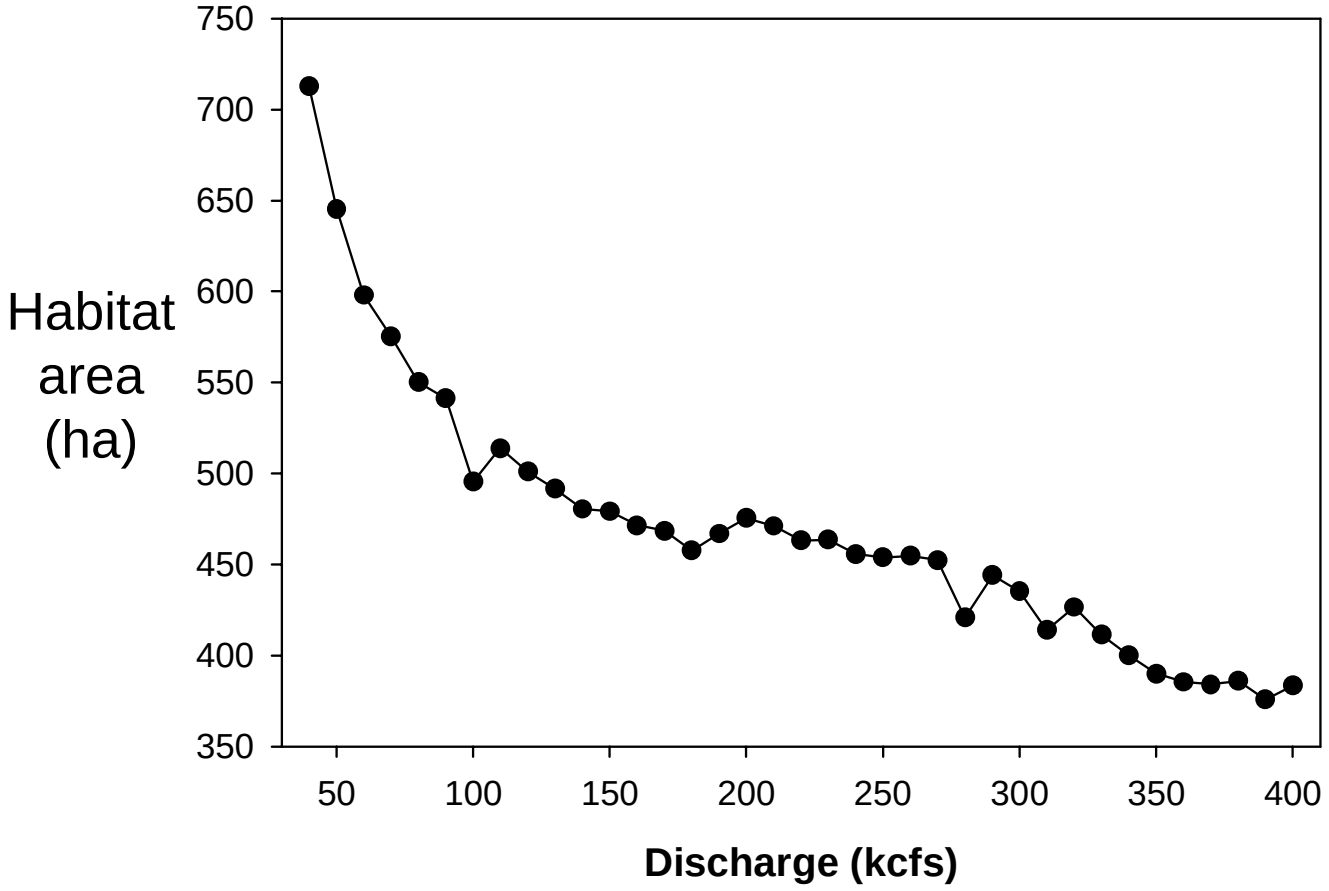


Spawning Habitat Summary

- A Reach-wide, geospatial quantitative assessment is complete for providing the physical framework to evaluate the effect of flows and flow fluctuations on spawning habitat
- Exploratory analysis identified influential habitat characteristics
  - Persistence of suitable velocity was an important variable
- Suitable spawning habitat increases with flow
- After spawning habitat analyses are completed:
  - Useful for managing flows under various escapement levels
  - Quantify the spatial distribution of spawning habitat
  - Evaluate the effects of operational alternatives on the quantity and distribution of spawning habitat

Rearing Habitat

- Used model developed by Tiffan et al. (2002) to predict amount and location of rearing habitat



Conclusions

Collaboration:

- This study was a highly collaborative effort among nine federal, state, tribal and consultant organizations.

Hydrodynamic Modeling:

- The hydrodynamic models applied in this study provide a useful tool for characterizing physical habitat conditions across the Reach.

Juvenile Entrapment:

- We estimated that 1.6 million Chinook were entrapped in 2003.
- These entrapment impacts are significantly higher than previous estimates of stranding and entrapment.
- Simulations demonstrate that operational alternatives can reduce the level of entrapment mortality on rearing fall Chinook.
- The re-regulation analyses demonstrate the physical capacity to reduce flow fluctuations during the rearing period.

Conclusions

Spawning Habitat:

- The high concentration of spawning in the White Bluffs/Locke Island area argues for their management focus.
- Spawning habitat selection under the variable conditions is highly complex. However, habitat persistence was found to be an important underlying mechanism.
- Factors determining redd site selection vary along the Reach; area-specific models may be required.

Overall:

- These results provide useful information and tools for fishery managers and regulators for determination of appropriate river operations to accommodate fall Chinook during their spawning and rearing periods.